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Gold, copper mining and geoarcheology in Central Bulgaria

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1. Introduction: geology and history

1.1 Brief introduction to the structure and geodynamics of the Balkan Peninsula

(Christo Dabovski)

Since the pioneering studies of Cvijić (1904), the Alpine orogenic belts on the Balkans have been for a long time traditionally subdivided into two systems (branches): (1) a northern, dominantly E- to N-verging (Carpathians and Balkanides) and (2) a southern, SW- to S-verging (Dinarides and Hellenides). The Rhodope and Serbo-Macedonian massifs were understood as stable blocks separating the two orogenic systems. More recent studies have shown that these massifs were repeatedly deformed and involved in the tectonic events that generated the Balkan orogen (*e.g.* Burg *et al.*, 1996) and in fact should be included in the orogenic architecture. Thus, if we accept the notion of two orogenic systems of opposite vergence, then the boundary between them can be placed along the Vardar zone, one of the main ophiolite sutures on the Balkans. The major sutures and tectonic units in this region are shown on a generalized tectonic scheme and two conceptual cross-sections (Figs. 1–3).

The Carpathians form an arcuate fold-and-thrust belt that merges to the west with the Alps and to the south with the Balkanides through a complex system of N–S strike-slip faults. The traditional tectonic zoning (Fig. 1) of the East and South Carpathians in Romania is based on the works of Sandulescu (1984, 1994). The innermost unit – the Inner Dacides outcrop in the Apuseni Mts as a system of N-verging thrust sheets of pre-Mesozoic metamorphic rocks and Mesozoic, mainly carbonate platform sequences. The Transylvanides likewise form a N-verging thrust complex of Lower–Middle Jurassic ophiolite and island-arc assemblages, which override the Inner Dacides. This unit is interpreted as the suture zone of a Jurassic ocean that opened during the Early Jurassic and closed in Mid-Cretaceous time. The Median Dacides (Supragetic and Getic nappes) comprise pre-Mesozoic metamorphic and magmatic basement complexes and Mesozoic sedimentary sequences. The Outer Dacides (Severin and Ceahlau nappes) are a thrust sheet complex of Jurassic–Lower Cretaceous turbidites and minor ophiolites. The Marginal Dacides (Danubian), exposed in a tectonic window below the Getic nappes, are composed of Precambrian and Paleozoic basement rocks, covered by a relatively thick succession of Mesozoic shallow- to deep-marine sediments. The Moldavides comprise mainly Hauterivian– Barremian to Mid-Sarmatian flysch sediments, thrust towards the foreland (Scythian and Moesian platforms) and partly overriding the shallow-

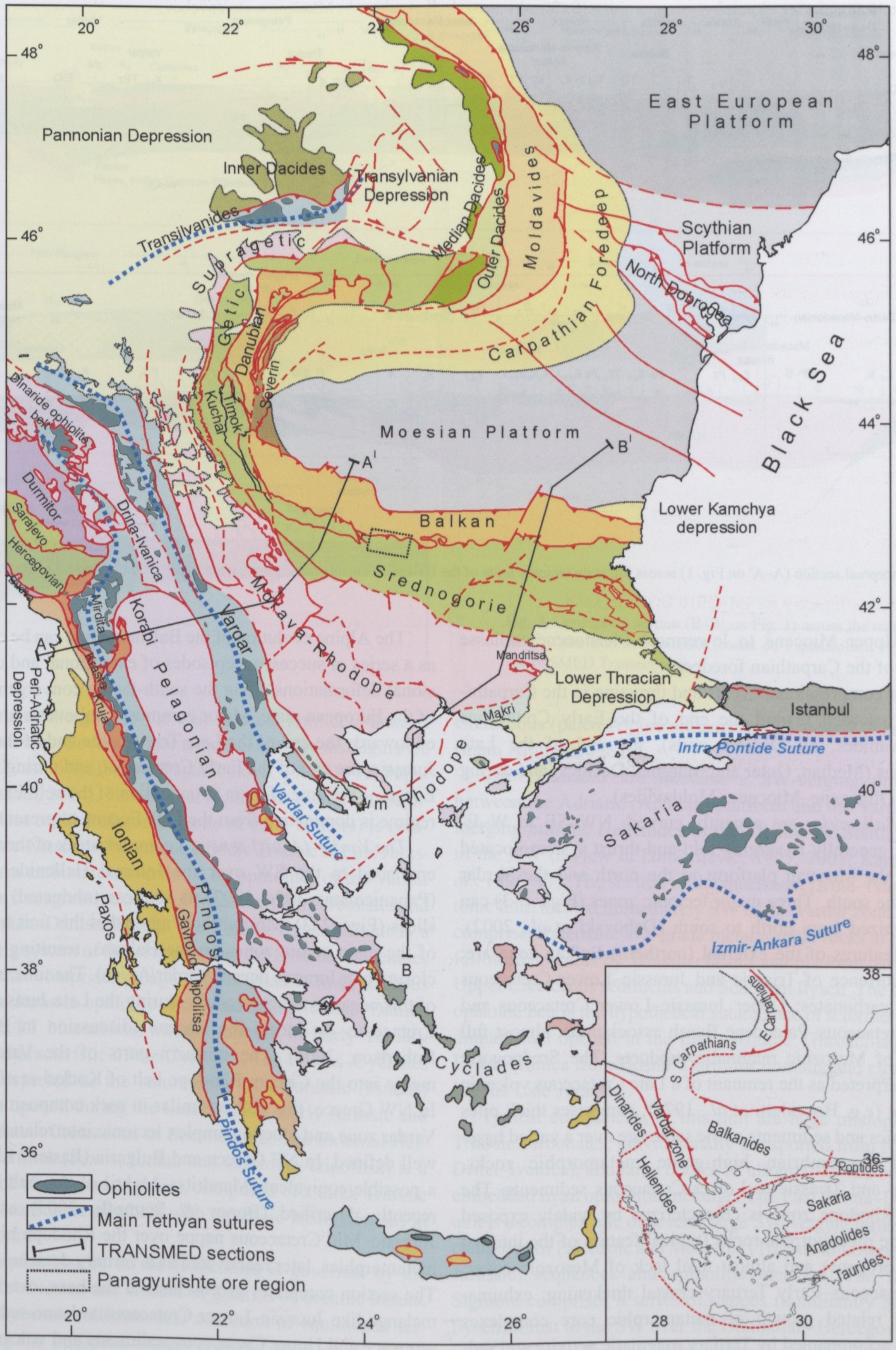

Fig. 1. Orogenic belts and major tectonic units on the Balkans (based on Săndulescu, 1994; Dimitrijević, 1999; Kräutner & Krstić, 2003; Bornovas, 1983; Papanikolaou *et al.*, 2004; Carminati *et al.*, 2004; Dabovski *et al.*, 2002; Okay & Tüysüz, 1999)

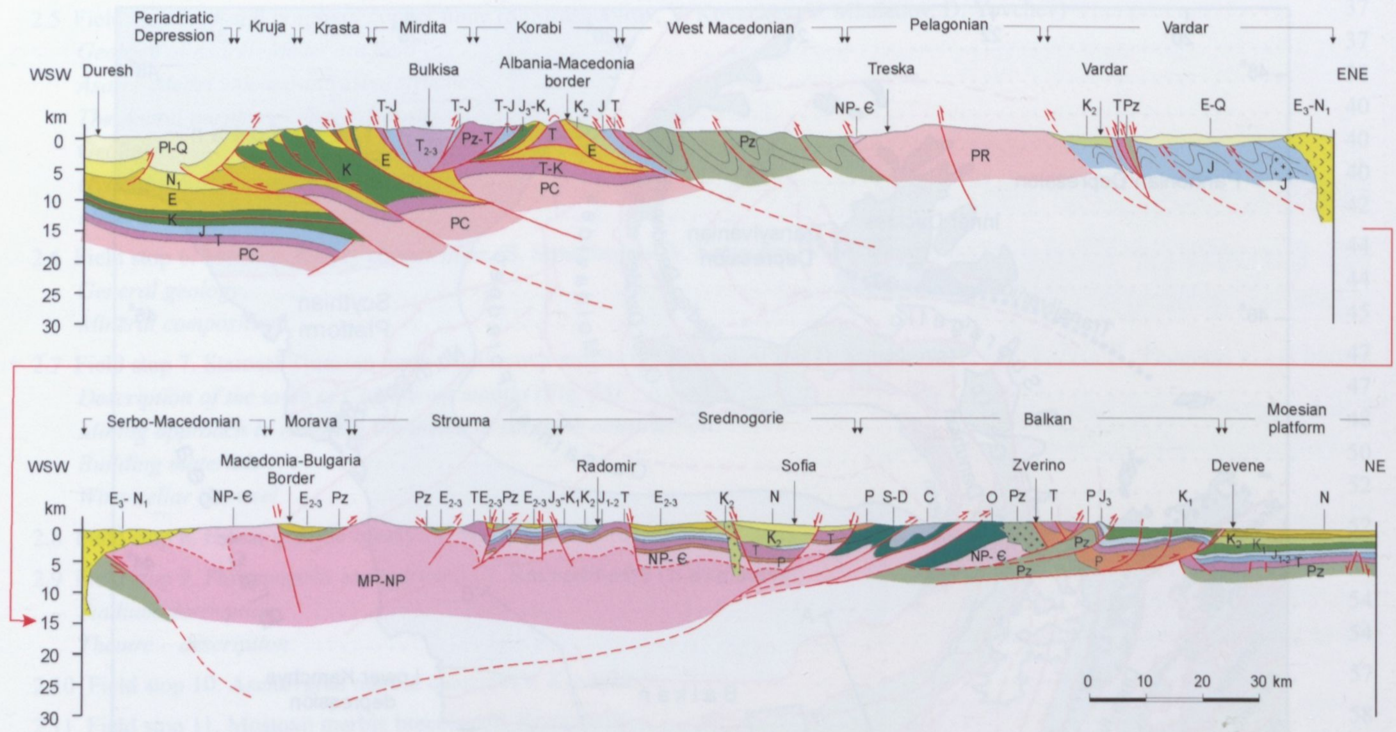

Fig. 2. Conceptual section (A–A' on Fig. 1) across the main tectonic units of the Balkan Peninsula (based on Gaetani *et al.*, 2004, TRASNSMED Transect III)

marine Upper Miocene to lowermost Pleistocene molasse deposits of the Carpathian foredeep.

Major compressional events and thrusting in the Carpathians are recorded toward the end of the Early Cretaceous (Transylvanides, all Dacidic units), the end of the Late Cretaceous (Median, Outer and Marginal Dacides) and during the Late Oligocene–Miocene (Moldavides).

The Balkanides are a gently curved, NW–SE to W–E-trending, generally N-verging fold-and-thrust system, located between the Moesian platform to the north and the Vardar zone to the south. Three major tectonic zones (Figs. 1–3) can be recognized from north to south (Dabovski *et al.*, 2002). Typical features of the external (northern) Balkan zone are: wide occurrence of Triassic and Jurassic–Lower Cretaceous platform carbonates; Upper Jurassic–Lower Cretaceous and Upper Cretaceous–Paleocene flysch associations; almost full absence of Mesozoic magmatic products. The Srednogorie zone, interpreted as the remnant of a Late Cretaceous volcanic island arc (*e.g.* Boccaletti *et al.*, 1974), comprises thick piles of volcanics and sediments of the same age over a varied basement of Precambrian high-grade metamorphic rocks, Paleozoic and Triassic to Lower Cretaceous sediments. The Morava–Rhodope zone is characterized by widely exposed high-grade metamorphic rocks (typical feature of the internal parts of orogens) and almost total lack of Mesozoic cover; Late Cretaceous–Early Tertiary crustal thickening; exhumation and related growth of metamorphic core complexes (domes), accompanied by Tertiary magmatic activity and sediment deposition in basins between the domes (*e.g.* Ivanov, 2000; Khroe & Mposkos, 2002).

The Alpine evolution of the Balkanide belt can be described as a series of successive episodes of extensional and compressional deformations along the south-facing convergent margin of the European plate. Major compressional events are recorded towards the end of the Late Triassic, the end of the Middle Jurassic, the end of the Early Cretaceous, and during the Mid-Eocene – the time of main structuration of the belt. Extensional regime is dominating from the Late Eocene to present days.

The Vardar (Axios) zone is a complex stack of thrust sheets emplaced to the SW over the Internal Hellenide platform (Papanicolaou, 1996–1997) as rootless (obducted) ophiolite slices (Figs. 2–3). Most authors agree that this unit traces one of the main suture zones on the Balkans, resulting from the closure of a Jurassic ocean (Vardar/Axios). The time of closure of this ocean is controversial – during the Late Jurassic–Early Cretaceous or during the Eocene (discussion in Brown & Robertson, 2004). The northern parts of the Vardar zone merge into the Circum Rhodope belt of Kockel *et al.* (1971). In NW Greece, this belt is similar in rock composition to the Vardar zone and, due to complex tectonic interrelations, is not well defined. In NE Greece and Bulgaria (Eastern Rhodope), a possible equivalent (Mandritsa–Makri) of this belt has been recently described (Bonev & Stampfli, 2003) as a Late Jurassic–Mid Cretaceous nappe over the Rhodope high-grade metamorphics, later reactivated as a Tertiary detachment fault. The section comprises greenschists at the base, overlain by a melange-like Jurassic–Lower Cretaceous volcano-sedimentary sequence and Upper Cretaceous sediments and volcanics.

The Hellenides form a SW- to S-verging thrust belt that extends across continental Greece and the Aegean islands to the

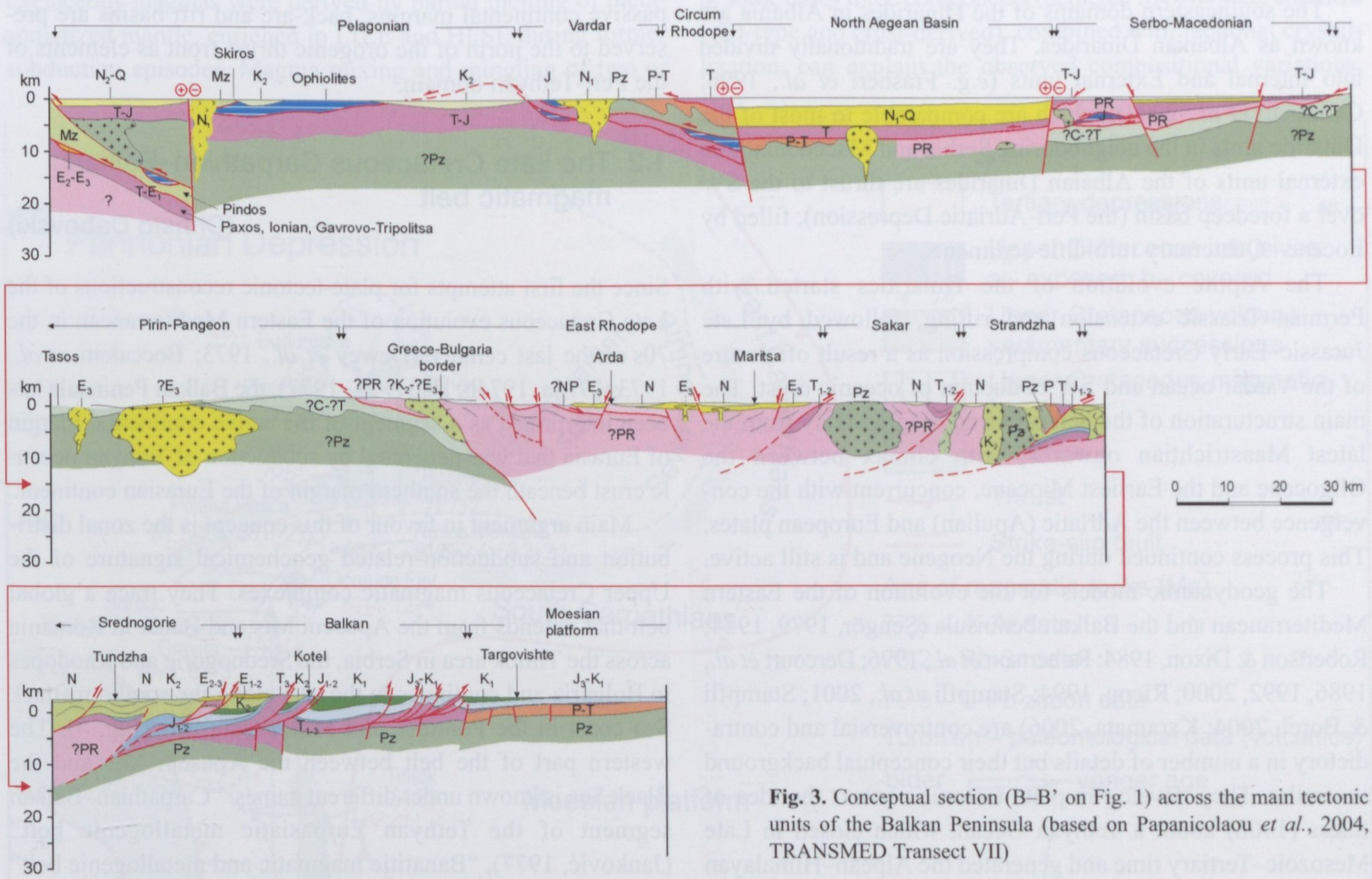

Fig. 3. Conceptual section (B–B′ on Fig. 1) across the main tectonic units of the Balkan Peninsula (based on Papanicolaou *et al.*, 2004, TRANSMED Transect VII)

Turkish coast, merging to the east into the Pontides, Sakaria and the Taurides. Several major tectonic units are distinguished from northeast to southwest (Papanicolaou, 1996–1997; Papanicolaou *et al.*, 2004). The internal Hellenides platform (roughly equivalent to the Pelagonian zone of other authors) is composed of pre-Mesozoic basement, Middle Triassic to Late Jurassic platform carbonates, overthrust by ophiolites of the Vardar unit, and a transgressive cover of Maastrichtian carbonates and Maastrichtian–Danian flysch. The Pindos–Cyclades unit is a SW-verging system of thrust sheets over the External Hellenides platform that comprises pelagic Upper Triassic to Cretaceous sediments, Jurassic ophiolite slices and Maastrichtian–Danian flysch. HP/LT blueschists, metamorphosed in Early Tertiary time, are characteristic of the Cyclades. The Pindos–Cyclades unit is interpreted as the suture zone of a Jurassic (Pindos) ocean that opened during the Late Triassic–Early Jurassic and closed in latest Cretaceous to Eocene time. The External Hellenides platform (Paxos, Ionian and Gavrovo–Tripolitsa) is a fragment of Gondwana (Apulia), composed of a thick Triassic to Eocene carbonate platform with a pelagic basin (Ionian) in the axial part.

The Alpine history of the Hellenides is governed by the opening, subduction and closure of a series of oceanic basins, followed by microcollisions and accretion of continental terranes along the European margin (Papanicolaou *et al.*, 2004). Major orogenic events, related to terrane accretion, are recorded in Late Triassic (Cimmeride orogeny), Late Jurassic–Early Cretaceous (paleo-Alpine orogeny) and Eocene-Miocene time (main Alpine orogeny).

The Dinarides are likewise a SW-verging thrust belt between the Adriatic (Apulian) platform and the Vardar zone, merging into the Hellenides to the SE and the Southern Alps to the NW (review in Dimitrijevič, 1995, 2001; Karamata *et al.*, 1996–97). The section of the innermost Drina–Ivanica tectonic unit, located immediately SW of the Vardar zone (Fig. 1), comprises Paleozoic low-grade metamorphic rocks at the base, followed upwards by Triassic clastics and platform carbonates, Upper Cretaceous sediments and Senonian flysch. The Dinaride ophiolite belt is the hypothetical suture zone of a former oceanic domain that opened in the Early–Middle Triassic, separating Drina–Ivanica from Bosna–Durmitor domain, and closed during the Late Jurassic.

Typical components of this unit are huge olistoplakas of Triassic carbonates, gravitationally transported from NE (form Drina–Ivanica), and large bodies of ultramafics and ophiolites embedded in an ophiolitic melange. The East Bosna–Durmitor unit is a complex pile of several large SW-verging thrust sheets, composed of Paleozoic and Mesozoic (Triassic to Lower–Middle Jurassic) sequences and ophiolitic melange. The Sarajevo Sigmoid comprises a series of nappes (dominantly Senonian flysch) thrust to the SW over the Dalmatian–Hercegovian unit – a thick Upper Triassic to Paleocene carbonate platform. The Budva zone comprises a rather condensed Mesozoic section covered by thick Oligocene flysch.

The southeastern domains of the Dinarides in Albania are known as Albanian Dinarides. They are traditionally divided into Internal and External units (*e.g.* Frasheri *et al.*, 1996; Carminati *et al.*, 2004), which are comparable to most of the Dinaride units in the neighbouring Serbia and Macedonia. The external units of the Albaian Dinarides are thrust to the SW over a foredeep basin (the Peri-Adriatic Depression), filled by Eocene– Quaternary turbiditic sediments.

The Alpine evolution of the Dinarides started with Permian–Triassic extension and rifting, followed by Late Jurassic–Early Cretaceous compression as a result of closure of the Vardar ocean and SW obduction of oceanic crust. The main structuration of the belt occurred progressively from the latest Maastrichtian onwards, with climax between the Oligocene and the Earliest Miocene, concurrent with the convergence between the Adriatic (Apulian) and European plates. This process continued during the Neogene and is still active.

The geodynamic models for the evolution of the Eastern Mediterranean and the Balkan Peninsula (Şengör, 1979, 1984; Robertson & Dixon, 1984; Robertson *et al.*, 1996; Dercourt *et al.*, 1986, 1992, 2000; Ricou, 1994; Stampfli *et al.*, 2001; Stampfli & Borel, 2004; Karamata, 2006) are controversial and contradictory in a number of details but their conceptual background is similar. They develop in plate tectonic context the idea of Suess (1908) about a Tethyan Ocean, which closed in Late Mesozoic–Tertiary time and generated the Alpean–Himalayan fold-and-thrust belt. The basic differences between the different concepts concern the number and time of opening and closure of the oceanic basins in the Tethyan realm.

The most popular concepts may be divided into three groups: (1) Tethys is a vanished Mesozoic ocean that opened towards the end of the Permian or the beginnig of the Triassic and closed during the Late Eocene, generating the Alpine orogen as a suture zone of the closed ocean (Ricou, 1994); (2) Tethys is a system of two oceanic basins (Paleo-Tethys and Neo-Tethys, which successively opened and closed one after the other and generated two superimposed orogens – Cimmerides (product of the Paleo-Tethys) and Alpides (product of the Neo-Tethys) as components of the Tethysides (Stöklin, 1974; Şengör, 1979, 1985; Şengör & Yilmaz, 1981); (3) Tethys includes a number of oceanic basins that opened and closed in different time and generated separate fold-and-thrust belts that form today the complex edifice of the Alpine fold-and-thrust belt (Ziegler *et al.*, 2001; Stampfli *et al.*, 2001; Stampfli & Borel, 2004).

The scenario of the most recent and popular thrid group of models assumes continuous (Late Paleozoic–Teriary) subduction of Paleotethyan and Neotethyan oceanic lithosphere to the north below Eurasia. As a result, a series of back-arc basins of different age and location opened and closed along the southern margin of the continent. The closure of these heterogeneous oceanic domains produced a system of discrete orogenic belts of diverse tectonic setting, timing of deformation and internal architecture that now from the Alpine orogen in the Eastern Mediterranean and the Balkan Peninsula. Relics of passive continental margins, back-arc and rift basins are preserved to the north of the orogenic thrust front as elements of the Peri-Tethyan domain.

1.2 The Late Cretaceous Carpathian–Balkan magmatic belt

(Christo Dabovski)

Since the first attempts for plate-tectonic reconstructions of the Late Cretaceous evolution of the Eastern Mediterranean in the 70s of the last century (Dewey *et al.*, 1973; Boccaletti *et al.*, 1973, 1974a, 1974b; Hsü *et al.*, 1977), the Balkan Peninsula has been interpreted as a segment of the active continental margin of Eurasia that was generated by subduction of Tethyan oceanic crust beneath the southern margin of the Eurasian continent.

Main argument in favour of this concept is the zonal distribution and subduction-related geochemical signature of the Upper Cretaceous magmatic complexes. They trace a global belt that extends from the Apuseni Mts and Banat in Romania across the Timok area in Serbia, the Srednogorie and Rhodopes in Bulgaria and continues to the east along the southern Black Sea coast in the Pontides and Minor Caucasus (Fig. 4). The western part of the belt between the Apuseni Mts and the Black Sea is known under different names: "Carpathian–Balkan segment of the Tethyan Euroasiatic metallogenic belt" (Janković, 1977), "Banatitic magmatic and metallogenic belt" (Berza *et al.*, 1998) or "Apuseni–Banat– Timok–Srednogorie magmatic and metallogenic belt" (Popov *et al.*, 2002).

The Carpathian–Balkan magmatic belt forms a SW convex arc striking approximately N–S between the Apuseni and Timok area, and E–W in the Bulgarian Srednogorie. Its length is about 1000 km and the width is 30 to 120 km. In general the belt follows the trends of the thrust fronts in the Carpathian–Balkan orogen except for its northern termination where it intersects almost transversally the structures of the Transylvanian ophiolitĺ belt (suture) and Apuseni Mts (Fig. 4).

The belt is outlined by linearly arranged volcano-sedimentary sequences, preserved in deformed trough-like structures, and different in size plutonic bodies intruding pre-Upper Cretaceous rocks in adjacent uplifted blocks.

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The compositional trends vary from tholeiitic to super K-alkaline with dominating calc-alkaline and high-K calc-alkaline types (Popov *et al.*, 2002; Ciobanu *et al.*, 2002). The available trace-element data for some better studied magmatic centres are in favour of subduction-related island-arc origin of the rocks (Ciobanu *et al.*, 2002). Chondrite- and MORB-normalized models, some indicative trace-element ratios and various types of geochemical discrimination diagrams support this concept. New data from the Bulgarian Srednogorie (Kamenov *et al.*, 2007; Dabovski *et al.*, 2009) suggest that the Upper

Cretaceous magmas were derived by partial melting of metasomatized mantle, enriched in LILE and HFSE during former subduction episodes. Magma mixing and mingling of two or in some cases three components (depleted MORB-like, enriched OIB-type and crust-derived), combined with factional crystallization, can explain the observed compositional variations,

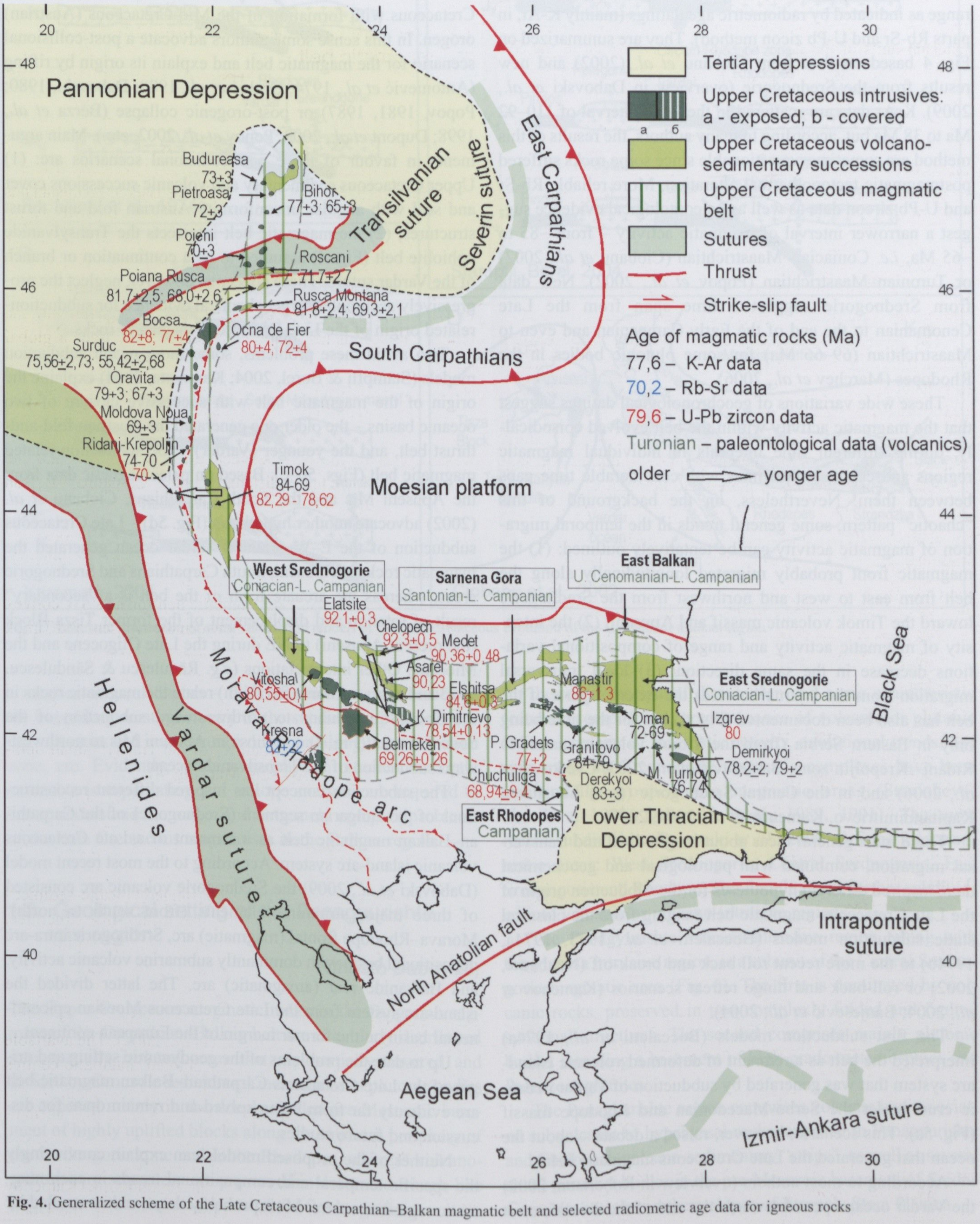

Fig. 4. Generalized scheme of the Late Cretaceous Carpathian–Balkan magmatic belt and selected radiometric age data for igneous rocks

trace element and isotope patterns (Dabovski *et al.*, 2009 and references therein). The subduction components (slab-derived fluids and melts) prevail over continental crust contamination.

The age of magmatic rocks within the belt varies in a wide range as indicated by radiometric age datings (mainly K-Ar, in parts Rb-Sr and U-Pb zicon method). They are summarized on Fig. 4 based on data from Ciobanu *et al.* (2002) and new results from the Srednogorie (overview in Dabovski *et al.*, 2009). K-Ar data are scattered in the wide interval of 110–92 Ma to 38 Ma but, according to many authors, the results of this method are sometimes questionable since some rocks suffered postmagmatic tectonothermal alteration. More reliable Rb-Sr and U-Pb zircon data as well as paleontological evidence suggest a narrower interval of magmatic activity – from ~85 to ~65 Ma, *i.e.* Coniacian–Maastrichtian (Ciobanu *et al.*, 2002) or Turonian–Maastrichtian (Popov *et al.*, 2002). New data from Srednogorie suggest a time span from the Late Cenomanian to the end of the Early Campanian and even to Maastrichtian (69–66 Ma) for some plutonic bodies in the Rhodopes (Marchev *et al.*, 2006).

These wide variations of geochronological datings suggest that the magmatic activity within the belt evolved episodically, during different time intervals in individual magmatic regions and centres, sometimes with considerable time gaps between them. Nevertheless, on the background of this "chaotic" pattern, some general trends in the temporal migration of magmatic activity can be tentatively outlined: (1) the magmatic front probably migrated longitudinally along the belt from east to west and northwest from the Srednogorie toward the Timok volcanic massif and Apuseni; (2) the intensity of magmatic activity and range of compositional variations decrease in the same direction; (3) local transversal migration from the internal towards the external parts of the belt has also been documented (Fig. 4) but for the time being only in Eastern Serbia (from the Timok volcanic massif to Ridanj– Krepoljin zone, Banješević *et al.*, 2003; Cvetković *et al.*, 2006) and in the Central Srednogorie (from Elatsite to Kapitandimitrievo, Kamenov *et al.*, 2004, 2007).

These most general ideas about longitudinal and transversal migration, combined with petrological and geochemical data, inspired different hypotheses for the subduction origin of the Late Cretaceous magmatic belt ranging from the classical static subduction models (Boccaletti *et al.*, 1973, 1974a, 1974b) to the more recent roll back and break-off (Neubauer, 2002) or roll-back and hinge retreat scenarios (Kamenov *et al.*, 2004; Banješević *et al.*, 2004).

The first subduction models (Boccaletti *et al.*, 1974a) interpreted the belt as a remnant of deformed volcanic island-arc system that was generated by subduction of Vardar oceanic crust under the Serbo-Macedonian and Rhodope massif (Fig. 5a). This scenario, however, raised a debate – about the ocean that generated the Late Cretaceous magmatic belt.

According to most authors (overview in Robertson, 2002) the Vardar ocean opened towards the end of the Triassic or at the beginning of the Jurassic and closed in the interval Late Jurassic–Early Cretaceous due to collision between the Pelagonian microcontinent and the Serbo-Macedonian massif, *i.e.* the subduction of Vardar oceanic crust terminated before the Late Cretaceous with formation of the Mid-Cretaceous (Austrian) orogen. In this sense some authors advocate a post-collisional scenario for the magmatic belt and explain its origin by rifting (Antoniević *et al.*, 1974; Grubić *et al.*, 1980; Dabovski, 1980; Popov, 1981, 1987) or post-orogenic collapse (Berza *et al.*, 1998; Dupont *et al.*, 2002; Popov *et al.*, 2002, etc.). Main arguments in favour of these post-collisional scenarios are: (1) Upper Cretaceous sedimentary and volcanic successions cover and seal with angular unconformity Austrian fold and thrust structures; (2) the magmatic belt intersects the Transylvanide ophiolite belt (Fig. 4) assumed to be a continuation or branch of the Vardar suture. These concepts, however, neglect the progressively accumulating geochemical evidence for subduction-related origin of the Late Cretaceous magmatic rocks.

Two avoid these problems, some more recent subduction models (Stampfli & Borel, 2004; Karamata, 2004) explaine the origin of the magmatic belt with successive closure of two oceanic basins – the older one generated the Austrian fold-and-thrust belt, and the younger (Vardar) – the subduction-related magmatic belt (Figs. 5b–c). Based on paleomagnetic data from the Apuseni Mts and the South Carpathians, Ciobanu *et al.* (2002) advocate another hypothesis (Fig. 5d) – Late Cretaceous subduction of the E–W oriented Vardar ocean generated the magmatic rocks in Apuseni, South Carpathians and Srednogorie areas, whereas the arcuate form of the belt is a "secondary" result of rotation and displacement of the former Tisza Block (the present Apuseni) to NE during the Late Oligocene and the Miocene. Other interpretations (*e.g.* Rădulescu & Săndulescu, 1973 and many authors after them) relate the magmatic rocks in the South Carpathians to northwestward subduction of the Severin ocean (Fig. 4) and those in Apuseni Mts to northwestward subduction of the Transilvanide ocean.

The subduction concept has inspired different reconstructions of the Bulgarian segment (Srednogorie) of the Carpathian–Balkan magmatic belt as a remnant of a Late Cretaceous volcanic island-arc system. According to the most recent model (Dabovski *et al.*, 2009) the Srednogorie volcanic arc consisted of three major structural elements (from south to north): Morava–Rhodope frontal (magmatic) arc, Srednogorie intra-arc depositional basin with dominantly submarine volcanic activity, and Balkanide rear (amagmatic) arc. The latter divided the island-arc system from the Late Cretaceous Moesian epicontinental basin on the former margin of the European continent.

Up to date the problems of the geodynamic setting and origin of the Late Cretaceous Carpathian–Balkan magmatic belt are evidently far from being solved and remain open for discussion and future studies.

Neither of the proposed models can explain convincingly the specific temporal and compositional trends in each magmatic region or centre. Most probably they were controlled by

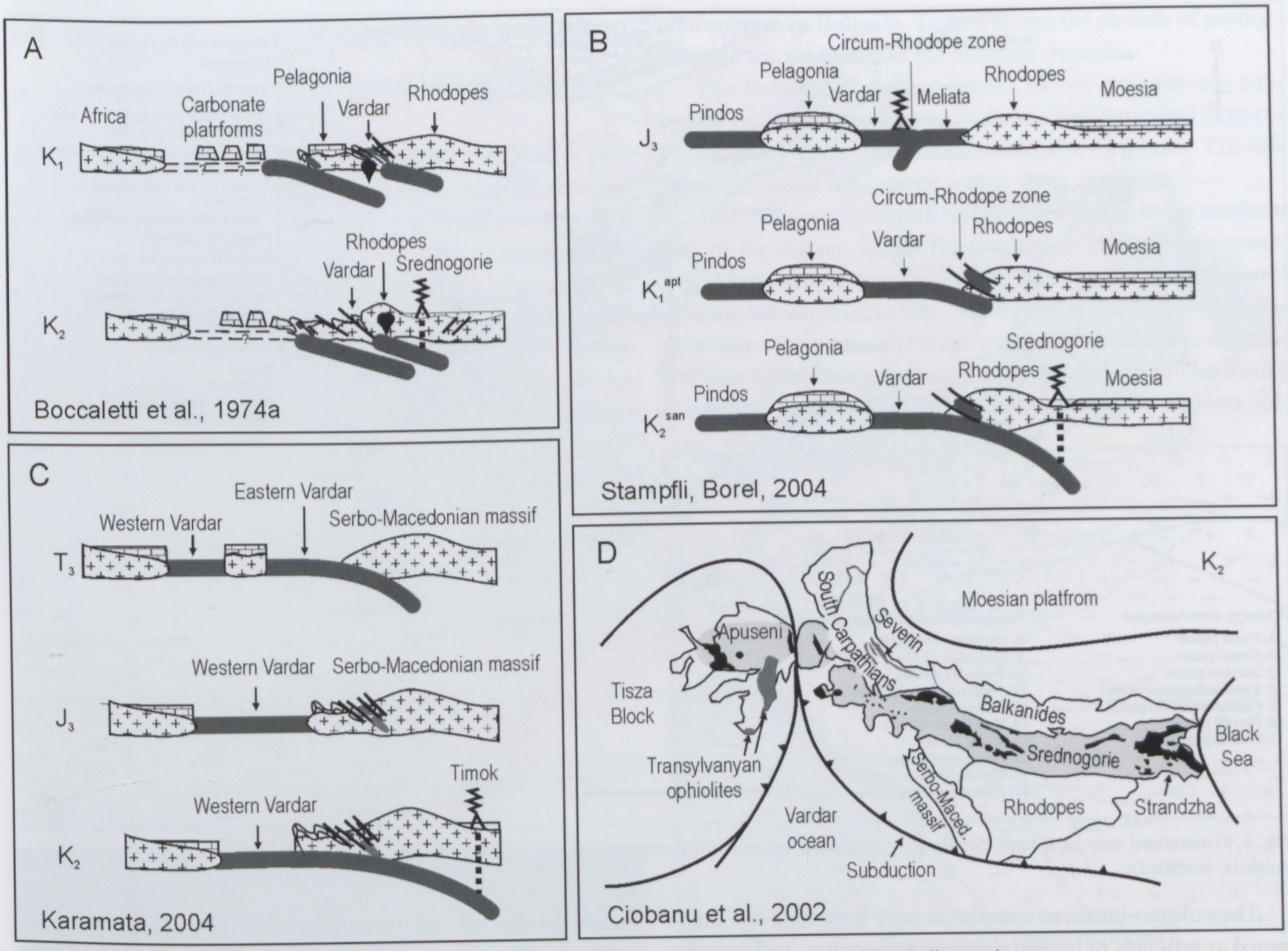

Fig. 5. Schematic illustration of some subduction models of the Late Cretaceous evolution of the Carpathian–Balkan region

a number of local factors – thickness and heterogeneities of the overriding crust, geometry of the subducting plate, changing velocities and convergence direction along the subduction zone, etc. Evidently, modern geophysical studies in depth, extensive isotope dating and isotope analyses are required to better understand the origin and extremely complex problems of the Late Cretaceous magmatism in the Balkan region.

1.3. Geological setting of the Panagyurishte ore region

(Christo Dabovski)

The Upper Cretaceous magmatic rocks in the Bulgarian segment of the Carpathian–Balkan belt are irregularly distributed into spatially isolated areas that are partially covered and divided by Cenozoic sediments. Linear chains of plutonic bodies are exposed mainly in the deeply eroded pre-Mesozoic basement of highly uplifted blocks along the southern periphery of the Srednogorie zone and in the Rhodopes, whereas volcano-sedimentary sequences are preserved in deformed trough-like structures within the axial parts of the Srednogorie.

Based on the spatial distribution and some characteristic features (composition, predominance of volcanic or plutonic facies, intensity of magmatic activity, evolutional trends, age span etc.), the Srednogorie magmatic complexes have been traditionally grouped into magmatic areas (Stanisheva-Vassileva, 1980; Dabovski *et al.*, 1989, 1991). The most recent subdivision (Dabovski *et al.*, 2009) defines four magmatic areas: West Srednogorie, Central Srednogorie, East Srednogorie and Rhodope. The first three are further subdivided into volcanic or volcano-intrusive regions.

The Panagyurishte volcano-intrusive region, along with the Maritsa intrusive region, is a subunit of the Central Srednogorie magmatic area (Fig. 6). The first is dominated by volcanic rocks, preserved in two complexly folded and faulted synclinal structures. The second comprises mainly plutonic bodies intruding a basement of high-grade metamorphics and Paleozoic granites.

The Panagyurishte region comprises volcanic and associated subvolcanic to hypabyssal rocks, exposed in Panagyurishte and Chelopech volcano-sedimentary "strips", as well as several small intrusive bodies in the pre-Mesozoic basement of Sredna Gora Mts and the northern slopes of Etropole Stara Planina.

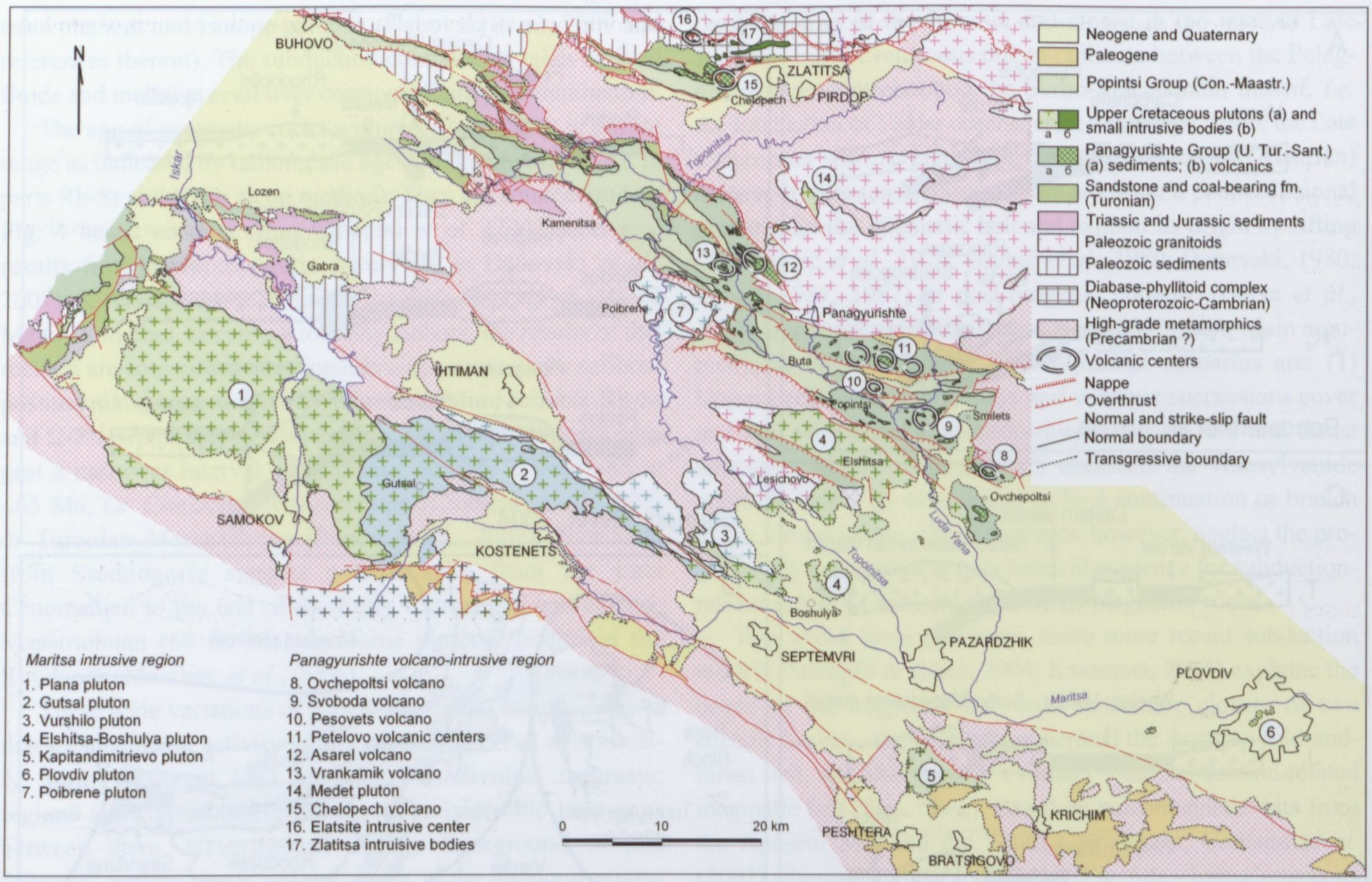

Fig. 6. Generalized map of Central Srednogorie magmatic region with Panagyurishte and Maritsa regions (based on the 1:100 000 Geological Map of Bulgaria, modified)

The volcano-intrusive complexes have been long ago interpreted as products of numerous magmatic centres, indicated by remnants of volcanic cones and small subvolcanic to hypabyssal bodies and dykes in their central parts (Ignatovski & Bairaktarov, 1996; Popov & Popov, 1997, 2000; Popov *et al.*, 2003; Popov, 2005). Most of them are located along a wide, probably fault-controlled NNW–SSE zone, traced by several magmatic centres from north to south: Elatsite, Chelopech, Medet, Asarel, Vrankamik, Petelovo, Pesovets, Svoboda, Ovchihalm and Elshitsa (Fig. 6). Only three of them (Elatsite, Chelopech, Asarel) are studied in more detail by modern petrological methods.

The volcanic products (pyroclastics and rare lava flows) in these centres show some petrographic variations but in general normal calc-alkaline (basaltic andesite, andesite, dacite, rhyolite) to transitional alkaline (shoshonite, latite, trachyte) rocks with calc-alkaline and high-K calc-alkaline signature prevail. Subvolcanic to hypabyssal bodies and dykes intrude the central parts of the paleovolcanoes or pre-Mesozoic basement rocks and consist of equigranular or porphyritic rocks, ranging in composition from diorite, quartz diorite, quartz monzodiorite and quartz monzonite to granodiorite and granite. The rock variations are controlled by processes of mingling and mixing of the partial magmas and fractional crystallization (Kamenov *et al.*, 2007).

The available paleontological and stratigraphic data (discussion in Dabovski *et al.*, 2009) suggest Late Turonian–Santonian age span of the magmatic activity in Panagyurishte region. U-Pb zircon data on some volcanic and intrusive rocks are scattered in a wider time interval (Late Turonian–Early Campanian) and reveal a distinct temporal migration of magmatic activity from north to south (von Quadt *et al.*, 2005; Kamenov *et al.*, 2007): 92–91 Ma (Elatsite, Chelopech), 90–89 Ma (Medet, Asarel), 86–80 Ma (Elshitsa).

$^{87}Sr/^{86}Sr$ initial ratios vary in the range of 0.70576–0.7050, indicating a mixed mantle-crustal origin of the parental magmas (Kamenov *et al.*, 2007). Nd, Hf and Pb isotope ratios support this concept and reveal that the mantle source is a mixture between enriched and depleted mantle sources. Chondrite- and MORB-normalized spidergrams for selected samples from volcanic and plutonic rocks suggest in most cases subduction-related volcanic-arc settings.

Recent detailed petrological, geochemical and isotope geochronological studies (Kamenov *et al.*, 2007) along a transect across Elatsite–Chelopech–Asarel–Elshitsa–Kapitan Dimitrievo magmatic centres reveal some regional trends in the Central Srednogorie magmatic region as a key to geodynamic interpretations: (1) temporal migration of magmatic activity from north to south; (2) crustal thinning in the axial (Elshitsa) part of the area; (3) decreasing involvement of crustal material in mantle-derived magma from older to younger magmatic centres, *i.e.* from north to south. These features have been tentatively explained by the slab/hinge retreat subduction model.

1.4. Metallogeny of the Panagyurishte ore region

(Strashimir Strashimirov & Veselin Kovachev)

The metallogeny of Panagyurishte ore region is defined in general by porphyry copper and copper massive sulphide deposits. Porphyry copper (± Mo) ores occur in the deposits of Medet, Asarel, Elatsite, Vlaikov Vruh, Tsar Asen (Fig. 7) and the subeconomic deposits of Orlovo Gnezdo, Karlievo, Popovo Dere, Kominsko Choukarche as well as numerous other occurrences (Bogdanov, 1987; Popov, 1996 and others). Massive sulphide ores are established in the Chelopech gold-copper deposit, the Krassen gold-bearing copper deposit, the copper-pyrite deposits Elshitsa and Radka, as well as numerous ore occurrences as Chervena Mogila, Stiptsata, Varnishka Choukara, Izgoreliya Vruh, Kaleto, etc. Usually, some copper-gold (Negurshtitsa) and gold-bearing lead-zinc-copper veins or mineralized shear zones (Vozdol, Svishti Plas) as well as barite veins (Kashana) are localized in the periphery of the ore fields. During the last decades the ore region is the main producer of copper ores and concentrates in Bulgaria. Table 1 shows the periods of production and the resources in the different deposits.

The location and development of ore deposits are controlled by the emplacement, evolution and structural features of the Upper Cretaceous volcano-intrusive structures. The different ore fields are located within these structures.

The Elatsite–Chelopech ore field is situated in the northern part of the region, within the Chelopech magmatic structure. The Asarel–Medet ore field is localized in the area of Asarel volcano-intrusive structure, northwest of the town of Panagyurishte. The Krassen–Petelovo ore field is related to the central part of the homonymous magmatic structure. The Radka ore field is located along the northern slope of the Elshitsa vol-

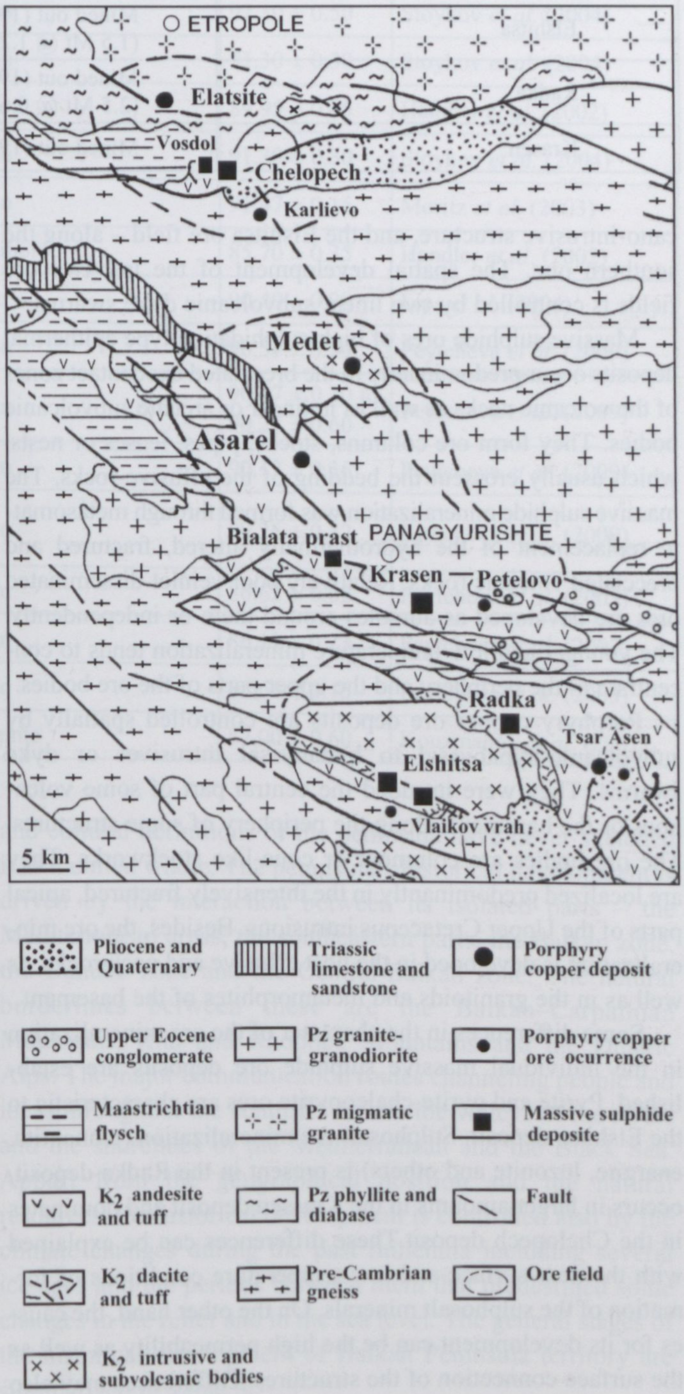

Fig. 7. Maps of Panagyurishte ore region and location of the porphyry copper and volcanic-hosted massive sulphide deposits

Left – satellite view with open pit porphyry copper deposits (yellow mark)
Right – schematic geological map with key deposits (Strashimirov et al., 2002, modified after Bogdanov, 1987)

Table 1. Copper deposits in the Panagyurishte ore region and their production and resources (data provided by the Bulgarian Ministry of Environment and Water, and actual data 2009 for the deposits in production)

Deposit	Remaining Resources	Past Production
Porphyry copper Asarel	142 Mt @ 0.41% Cu In production since 1976	175 Mt @ 0.47% Cu
Elatsite	154 Mt @ 0.33% Cu In production since 1981	260 Mt @ 0.39% Cu, 0.145 g/t Au
Medet	Mined out (1964–1993)	163Mt @ 0.32% Cu, 0.1 g/t Au
Vlaikov Vruh	Mined out (1962–1979)	9.8 Mt @ 0.46% Cu
Tsar Asen	Mined out (1980–1995)	6.6Mt @ 0.47% Cu
Volcanic-hosted sulphide Chelopech	31Mt @ 1.39% Cu, 3.5 g/t Au In production since 1954	17.8 Mt @ 1.17% Cu 3.245 g/t Au
Elshitsa	Mined out (1947–1996) (1.5 Mt @ 1.27% Cu)	2.5 Mt @ 1.0% Cu
Radka	Mined out (1942–1997) (2.5 Mt @ 0.6% Cu)	6.4 Mt @ 1.0% Cu
Krasen	Mined out (1962–1973)	0.30 Mt @ 0.76% Cu

cano-intrusive structure, and the Elshitsa ore field – along the southern one. The spatial development of the last two ore fields is controlled by two linear subvolcanic dyke swarms.

Massive sulphide ores of high-sulphidation type epithermal deposits occur predominantly in the brecciated exocontact zones of the volcanic necks as well as in linear or arcuate subvolcanic bodies. They form ore columns, stocks, pipes, lenses or nests, which usually crosscut the bedding of the effusive rocks. The massive sulphide mineralization was formed through metasomatic replacement of the hydrothermally altered, fractured and brecciated volcanic rocks. Relatively poor veinlet-disseminated ores are developed as aureoles around them or independently. The younger and low-temperature mineralization tends to concentrate in the periphery and the upper parts of the ore bodies.

Porphyry copper ore deposits are controlled spatially by subvolcanic-hypabyssal to hypabyssal intrusives or dyke swarms. They were intruded the central part of some volcanoes or the basement, along the periphery of some structures. The ore bodies are columnar or cone-like stockworks. They are localized predominantly in the intensively fractured, apical parts of the Upper Cretaceous intrusions. Besides, the ore mineralization is developed in the host effusive and neck rocks, as well as in the granitoids and metamorphites of the basement.

Some differences in the character of the ore mineralization in the individual massive sulphide ore deposits are established. Pyrite and pyrite-chalcopyrite ores are characteristic to the Elshitsa deposit. Sulphosalt ore mineralization (tennantite, enargite, luzonite and others) is present in the Radka deposit, occurs in larger amounts in the Krassen deposit and dominates in the Chelopech deposit.These differences can be explained with the near-surface and low-temperature conditions of formation of the sulphosalt minerals. On the other hand, the causes for its development can be the high permeability as well as the surface connection of the structures. Differences may also be explained by the variation in sulphidation state of the forming fluids.

Some differences in the character of the ore mineralization are established in the porphyry deposits as well. They are marked by the predominantly secondary chalcocite mineralization in Asarel, the higher content of molybdenite, the presents of PGE minerals in Elatsite and the payable content of molybdenum in Medet. These differences can be explained with the larger depth and/or reduction of permeability of the individual copper-molybdenum ore-bearing structures.

It is necessary to point out the different degree of development of the gold mineralization. The ore deposits in Elatsite–Chelopech ore field show the highest gold content. This enrichment can be possibly explained by the circumstance that the basement in this area consists of Riphean-Cambrian greenschist rocks containing larger amount of gold. Besides, the presence of ophiolite of the Thracian suture at depth could be another possible source of gold and platinum group elements in these ore deposits.

The geochronological studies of rocks and ores in the region can be divided into two periods. During the first period, the lead-isotope analysis data of the mineral deposits in Panagyurishte ore region (Amov & Vulkova, 1994) determined 130–225 Ma age by uranium-genetic lead and 115–135 Ma age by thorium-genetic lead. The results by thorium-genetic lead are more reliable, as the authors mentioned. At the same time the model parameter T is 3060–3200 Ma. These data show that the ore-forming processes have mobilized older lead from the basement rocks. The value of the model parameter T shows that it is related to source from the deepest part of the Earth's crust and partially from the upper mantle. The value of the thorium-genetic age probably indicates mobilization of substance that marks the time of Austrian tectonic deformations after the Aptian (113 Ma).

Table 2. Isotope age data from some of the main deposts in the Panagyurishte ore region

Object		Method	Age (Ma)	Authors
Elatsite	Intrusive	$^{40}Ar/^{39}Ar$ biotite	91.72 ± 0.70	Handler *et al.* (2002)
	Intrusive	$^{40}Ar/^{39}Ar$ amphibole	90.78 ± 0.44	Handler *et al.* (2002)
	Intrusive	$^{40}Ar/^{39}Ar$ amphibole	91.20 ± 0.60	Lips *et al.* (2004)
	Intrusive	$^{206}Pb/^{238}U$ zircon	92.10 ± 0.30	von Quadt *et al.* (2002)
	Intrusive	$^{206}Pb/^{238}U$ zircon	91.84 ± 0.31	von Quadt *et al.* (2002)
	Intrusive	$^{87}Sr/^{86}Sr$, $^{87}Rb/^{86}Sr$ – biotite, feldspar	90.55 ± 0.80	von Quadt *et al.* (2002)
	Ore deposit – ore mineralization	Re-Os molybdenite	93.10 to 92.30	Zimmermann *et al.* (2003)
Chelopech	Early subvolcanic intrusive	$^{206}Pb/^{238}U$ zircon	92.30 ± 0.50	Stoykov *et al.* (2004)
	Lava flow rocks	$^{206}Pb/^{238}U$ zircon	91.30 ± 0.30	Stoykov *et al.* (2004)
	Vozdol neck	$^{40}Ar/^{39}Ar$ biotite	89.95 ± 0.45	Handler *et al.* (2002)
	Vozdol neck	$^{206}Pb/^{238}U$ zircon	91.30 ± 0.30	Stoykov *et al.* (2004)
	Alterted and ore mineralized rocks	$^{206}Pb/^{238}U$ zircon	91.47 ± 0.15	Moritz *et al.* (2003)
Medet	Medet intrusive	$^{40}Ar/^{39}Ar$ amphibole	85.70 ± 0.35	Handler *et al.* (2002)
	Medet intrusive	$^{40}Ar/^{39}Ar$ biotite	90.40 ± 0.90	Lips *et al.* (2004)
	Intrusive – Q-monzodiorite porphyry	$^{206}Pb/^{238}U$ zircon	90.59 ± 0.29	Peytcheva *et al.* (2009)
	Intrusive – granodiorite porphyrites	$^{206}Pb/^{238}U$ zircon	90.47 ± 0.30 to 90.27 ± 0.60	Peytcheva *et al.* (2009)
	Intrusive – aplite dykes	$^{206}Pb/^{238}U$ zircon	90.12 ± 0.36	Peytcheva *et al.* (2009)
	Intrusive – late Q-granodiorite porphyrite dyke	$^{206}Pb/^{238}U$ zircon	89.26 ± 0.32	Peytcheva *et al.* (2009)
Elshitsa	Pluton – granite	$^{206}Pb/^{238}U$ zircon	86.62 ± 0.02	Peytcheva *et al.* (2003)
	Subvolcanic dacite	$^{206}Pb/^{238}U$ zircon	86.11 ± 0.23	Peytcheva *et al.* (2003)
Vlaikov Vruh	Hydrothermal rutile	$^{206}Pb/^{238}U$ zircon	85.66 ± 0.15	Peytcheva *et al.* (2003)
	Ore mineralization	Re-Os molybdenite	82.00 ± 0.60	Kouzmanov *et al.* (2001)

During the last years, several geochronologic studies have been performed on the basis of the $^{206}Pb/^{238}U$ zircon method by a team lead by von Quadt (von Quadt *et al.*, 2002; Peytcheva *et al.*, 2003; Peytcheva *et al.*, 2009; Stoykov *et al.*, 2004; Moritz *et al.*, 2003), the Re-Os molybdenite method (Zimmermann *et al.* 2003), and the $^{40}Ar/^{39}Ar$ method in biotite and amphibole (Handler İt al., 2002) and others. Table 2 summarises some age data obtained by different authors for some of the most important deposits in the region.

1.5. Short history of the Balkan Peninsula

(Kalin Dimitrov)

The geographical area of the Balkan Peninsula could be defined as the part of Southeastern Europe that lies between the Black, Aegean and Adriatic Sea. However, the historical and cultural definitions of the peninsula have never sketched it as a united whole. The peninsula's historical development is driven by the interaction between its isolated parts – the Mediterranean areas, the southeastern parts, the Balkan zone, the Danube zone and the Central-Balkan zone. The natural borderlines between these are the Balkan–Carpathian Mountains, Rila and Rhodope Mountains and the Dinaric Alps. The major communication routes channeling people and ideas throughout the centuries follow the valleys of the rivers and the shorelines of the Mediterranean and the Black Sea. Appart from the geographical position and the natural resources, the historical development is controlled also by the climate changes during the past millennia including several ice ages and the periods between them that predestined some changes in the relief and in the sea level. The general stages of the historical development of Balkan Peninsula territory are summarized in Table 3.

Table 3. Comparative chronological table of the cultural development of the Balkan Peninsula, the Bulgarian territory and the world

Historical age	Events and cultural monuments on Bulgarian territory	Events and phenomena on Balkan Peninsula	Events in Europe and the World
Middle Paleolithic (300,000–30,000)	Bacho Kiro cave, Kozarnika. Paleolithic tools and traces of habitats	Petralona cave findings – very archaic *Homo sapiens* (?) (200,000–150,000) *Yarimburgaz Cave*	The Neanderthals dominate. Before ~120,000 the early *Homo sapiens sapiens* appears
Late Paleolithic (50,000–12,000)	Bacho Kiro cave, Kozarnika Paleolithic tools and traces of habitats	*Yarimburgaz Cave* Franchthi Cave, Peştera cu Oase	The Neanderthals disappear and the contemporary human takes over all favourable areas; hunting; cave drawings; flint tools
Mesolithic (around 12,000–VIII[th] century BC)	Unstratified finds of microliths near Varna	Franchthi Cave – Greece, Hunting, technology of flint microliths and manufacture of composite tools; Findings of Lepenski vir; esolithic hunters exist together with early farmers	First colonization of Americas; The beginning of neolithization in Anatolia (X–VIII[th] century BC)
Neolithic (VIII–V[th] century BC)	Karanovo; Azmashka Mogila, Gradeshnitsa. The beginning of tells settlements; Dense network of settlements. Painted ceramics. Polished black ceramics	Cultivation of plants, growing of farm animals; permanent settlements; ceramics; stone and flint tools; use of regional natural resources; migration of farmers from Anatolia to the Balkans – around 7500 BC; increase of population	Neolithic settlements in Anatolia and Levant; scattered groups of hunters in Europe
Chalcolithic (V – the beginning of XIV[th] century BC)	People discover the first metals: copper and gold; development of metallurgy and metalworking technology – decorations and simple copper tools; copper deposits exploitations; first hierarchical patriarchal communities; Hotnitsa gold treasure; Durankulak Necropolis; Varna Necropolis; Settlements of tell type: Karanovo, Golyamo Delchevo	Development and spread of metallurgy and metalworking technologies	Neolitization of Central Europe; Copper import from the Balkan Peninsula
Bronze Age (IV–II[th] century BC)	Fortified settlements; settlement tells Ezero; Yunatsite; burial in tumuli; contacts with Anatolia and Central Europe; Dabene; Valchitran treasure	Development of aristocratic communities; construction of megaliths and stone fortresses; trade and over-regional exchange of luxury goods and materials; seafaring; development of bronze metallurgy and the use of metals in every day life; appearance of writing system and proto-city centres; Mycenae, Tiryns	Neolitization of Western and Northern Europe. Civilizations from Mesopotamia, civilization of Egypt; Minoan civilization; Trojan war
Early Iron Age (I[st] century BC)	Consolidation of Thracian tribes; mountain fortresses	Dorian invasion in Greece	Discovery of iron
Antiquity (VII[th] century BC–IV[th] century)	Thracian kingdoms and kings – Odrysae, Getae, Tribals; construction of tumuli, rich burial ceremonies: Kazanlak, Aleksandrovo, Starosel, Sveshtari. "Thracian treasures": Rogozen, Panagyurishte, Letnitsa, Borovsko; ancient cities on the Black sea coast: Dionysopolis; Odessos; Messambria; Appolonia; Roman cities: Philippoupolis Serdicae	Geek and Hellenistic civilization: polices, trade, philosophy, science, literature, art, architecture; Interaction with the "Barbarians" from the north; The Roman Empire on the Balkan Peninsula ([st] century): cities, large scale construction of private and community buildings and facilities; Romanization of the Balkans	Greek colonization in the Mediterranean sea. The Empire of Alexander the Great and the Hellenistic civilization; Development and enforcement of the Roman Empire; Romanization of Europe
Late Antiquity and Early Medieval (IV–VII[th] century)	Building of fortresses; Christianization of the population and building of basilicas	Breaking of the Roman Empire into Western and Eastern (395); Development of the Eastern Roman Empire and its transformation into the Christian Byzantine Empire with its own capital Constantinople	The conquest of Rome by the Barbarians (455); Barbarization of Western Europe

Historical age	Events and cultural monuments on Bulgarian territory	Events and phenomena on Balkan Peninsula	Events in Europe and the World
Medieval Age (VII–XIVth century)	Settling of Slavic and proto-Bulgarian tribe groups into the central parts of the Peninsula; Creation and development of the First Bulgarian Empire (681–1018); Byzantine rule (1018–1185); Renovation and development of the Second Bulgarian Empire (1185–1396)	Invasion of Barbarian tribes from the north and the east and their settling on the Peninsula; Byzantine Empire loses permanently control over the territory to the north of the Balkan Mountains; Creation of Medieval Balkan Empires and principalities; Christianization of the Peninsula	Empires and principalities of the Germans; Christianization of the Barbarian tribes; Appearance and spreading of the Islam; Frankish Empire; Medieval Age cities; Building of cathedrals; consolidation of the papacy; division of Catholics and Orthodox Christians; Crusades
Late Medieval Age (XIV–XVIth century)	Fall of the Medieval Bulgarian Kingdom and principalities (1371–1396) under Ottoman rule, Disappearance of the Medieval Bulgarian elite	Creation and consolidation of the Ottoman Empire; Fall of Constantinople in 1453; Destruction of the Christian Medieval Kingdoms on the Peninsula by the Ottomans: Bulgaria, Greece, Serbia (1389–1459), Prosperity of the Ottoman Empire and wars in Europe: conquest of most part of Hungary; siege of Vienna; rule over Eastern Mediterranean and North Africa; wars with Habsburg and Russian Empires	Renaissance; Book printing; Firearms; The great geographic discoveries; Reformation; Creation of centralized monarchies; Spanish and Portuguese colonies
New Age (XVII–XIXth century)	Development of the Bulgarian national bourgeoisie, development of the manufacture technology and the trade; redistribution of agricultural lands; rehabilitation of the Bulgarian Church (1872); development of the local authorities and of the Bulgarian education; commitment in uprisings against the Ottoman Empire: the April Uprising (1876)	Decline of the Ottoman Empire and decrease of the power of the sultan. Period of chaos and anarchy at the end of XVIIIth century; Splitting the "Ottoman heritage"; rise of the national bourgeoisies of the Balkan people; Creation of the Balkan countries: Greece (1821–1832), Serbia (1804–1817), Romania (1859–1878)	Foundation of USA; French revolution, Napoleonic Empire; Development of modern national countries; Colonial empires of Great Britain and France; Prosperity of Germany, Russia and Japan
Modern Age (XXth century)	Russian–Turkish war (1877–1878) and creation of the Third Bulgarian state, the Bulgarian principality (1878) after he treaty of Berlin; fast modernization, building of modern town facilities, railways, ports; creation of modern state institutions and education system; creation of army; declaration of independence (1906); war for unification with the Bulgarians outside the borders of the principality: First Balkan War (1912–1913), Second Balkan War (1913); Participation of Bulgaria in the First World War (1915–1918) in alliance with the Central Powers; after the war, the present-day borders of Bulgaria are set; the 1930s "golden years" – development of cities, authoritarian monarchy; signing of the Tripartite Pact and limited participation on the side of Germany in the Second World War (1941–1944); Alignment of Bulgaria with the Allies (1944–1945) at the end of the Second World War; Bulgaria – "the most trustful ally of USSR" (1947 –1989); Bulgaria becomes a member of NATO (2004); Bulgaria becomes a member of EU (2007)	Balkan Wars (1912–1913); Participation of the Balkan countries in World War I and World War II	World War I and the fall of the Ottoman Empire; The fall of Habsburg Empire; Russian Bolshevik Revolution; the foundation of USSR; Authoritarian regimes in the Balkan countries; World War II; Cold War; decolonization; fall of Berlin wall; disintegration of USSR, Yugoslavia and Czechoslovakia

The remnants of the most ancient, so far known, human ancestors that lived on the Balkan Peninsula have been discovered near Chirpan village (central southern Bulgaria) during the exploration of a former sand quarry. In 2008 among fossils of Late Miocene fauna a tooth of early hominid was discovered and dated at about 7 millions of years.

Following this finding the next traces of human presence on the Balkans are dated as Middle Paleolithic (about 200,000 years ago). In the area Zhelezni Vrata near Danube River, flint and stone tools are found as well as remnants of habitats. They revealed that the ancestors of the today's human lived in groups of several individuals and were hunters. The major achievements of these humans were the ability to make fire and to elaborate very few varieties but still effective stone and flint tools.

The end of the last Ice Age and the withdrawal of the ice coverage leading to slow warming of the climate began about 18,000 years ago. This is contemporary with the large-scale migration of the contemporary human (Homo sapiens sapiens) in the Old World. These events took place in the Mesolithic archaeological age. It is characterized by the development of the so-called microlithic technique of flint making. The people began to use composite tools made of many small and regular shaped flint lamellae mounted on wooden, antler and bone handles. (Fig. 8). Also developed were special tools and weapons such as the archery. The Mesolithic people, like their ancestors, found food by hunting and concentrated findings of their encampents are registered again in the area of Zhelezni Vrata on Danube River and also in the area of Bosphorus. The Mesolithic population was not numerous and lived in small groups. Well-preserved sites of this age are not found on Bulgarian territory. Several collections of microliths of unclear context are described and collected on the ground surface in the area of the town of Varna. These are dated using their typology as IX–VII[th] millennium BC.

At the same time the people in the Iranian Plateau and Anatolia began cultivating the first wheat cultures and growing goats and sheep as farm animals. The development of early farmer techniques was concentrated in areas of extremely favourable climate that continuously expanded northwards and northwestwards due to the increasing average annual temperatures and annual precipitation in the period 10,000–5000 BC. This transition from appropriating to producing economy is named neolithization and has the following general characteristics:

- Permanent settling of the population as a direct result of the new economy system and construction of relatively massive homes.
- Fast densification of the population; it is related to the production and the accumulation of food supplies.
- Important technological discoveries: ceramic vessels for food preparation and polished stone tools used for preparation of plant food, for agricultural purposes and construction of buildings;
- Construction of complex ideological systems related to the natural cyclic phenomena.

The appearance of the first farmers on the Balkans is the result of the fast increase of the density of population and the advancing of the favourable climate zones to the north leading to constant colonization of new territories. Neolithic people migrated from Anatolia to the Balkans (probably part of them by sea vessels) at the end of the VIII[th] millennium BC and settled down in the favourable places on the coastline in the area of Thessaly and at the Maritsa River estuary. Some groups of this community migrated to the north and to the west using the valleys of Struma, Vardar, Iskar and Maritsa rivers. For about one thousand years the farmers reached the middle Danube River, leaving many new settlements on their way. Usually these set-

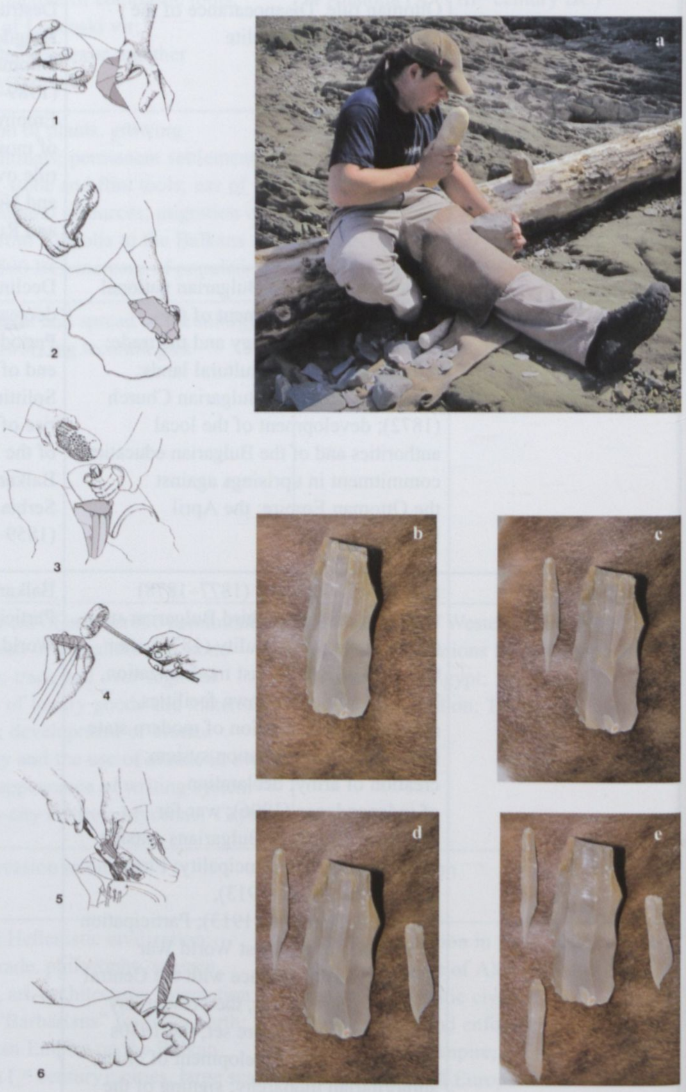

Fig. 8. Different techniques for flint processing by means of blow and pressure
a – Experimental processing of flint with wooden pestle, Late Paleolithic technique (photo K. Dimitrov, Experimental Archaeology M. Biar) 1 – by means of blow with hard stone pestle; 2 – by means of blow with deer horn pestle; 3 – by means of blow with wooden pestle via deer horn; 4 – indirect processing through counter-blow; 5 – by means of pressure with stomach "crutch"; 6. processing of flint surface through pressure in the hand palm (after Technologie de la pierre tallée) (photo: K. Dimitrov, Experimental Archaeology M. Biar)
b, c, d, e – Successive phases of exploitation of a flint kernel, re-assembly

tlements contained from 3–4 to several tens of ground constructions made by the pisé (rammed earth) technique (stakes stitched by a wattle covered by clay = wattle-and-daub structure), usually with a groundspace of about 15–25 to 30–40 m². In every house there was an oven, many ceramic vessels and often also looms and other home tools were found. The ceramics of the early farmers are skillfully made and decorated by complex colourful geometric or floral motifs (Fig. 9).

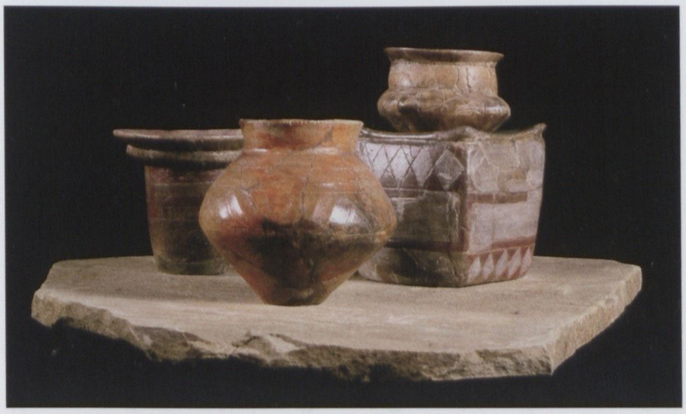

Fig. 9. Hand-made pottery, prehistoric necropolis near Durankulak village, Dobrich District, Chalkolithic, Vth millennium BC (photo: K. Dimitrov)

The tools are made of hard rocks or of flint. The most common are stone axes and large flint lamellae for mounting as working part of different tools.

The stable development of the Balkans in the period VII–IVth millennium BC allowed the villages to exist at the same location for more than three millennia in more favourable regions. This and the technology used for building the house constructions lead to the accumulation of many meters of cultural layers forming the so called "tells". The biggest tells are today discovered in Greece, Bulgaria, Romania and are more than 15 m high, forming large hill-like structures with characteristic profile that stand out in the planes or in hilly areas.

Fig. 10. Copper tools and decorations from funerals in Durankulak Necropolis: decorative bracelets and rings, end of Vth millennium BC (photo: K. Dimitrov)

The end of the stone ages according to the archaeological periods (Paleolithic, Mesolithic and Neolithic) is marked by the introduction of copper and gold as the first metals used by the ancient man. At first the people collected pieces of copper and worked them mechanically by cold hammering, boring, grinding and polishing. Such copper pieces are easily found in areas where a supergene enrichment zone of a copper deposit is exposed to the surface. The investigations show that the earliest copper tools and ornaments found in Europe are located in the Balkans at the beginning of the Vth millennium BC. These findings mark the beginning of the Chalcolithic Age (Fig. 10). Even in these early years the population of the Balkans began melting the copper, to produce metal from ore and to cast massive tools. The beginning of metallurgical technology development on the territory of Bulgaria is marked by several types of findings made of over 999‰ pure copper. These are various decorations (beads, bracelets, rings) and tools (awls, chisels, flat axes and hammer-axes). At the same time also the first golden objects appeared.

In spite of the achievements of the Chalcolithic metallurgy, it has one important weakness –pure copper (the main metal used) is too soft and cannot substitute for the stone and the flint tools. This problem was solved through the natural development of exploration, production and metallurgy. When the surface deposits of native copper were exhausted, the ancient "mine engineers" discovered the sulphide copper minerals located usually deeper under the ground surface. Probably, during the melting of such materials to produce copper, the people found the good influence of impurities such as As and Sb to the metal properties. This event marks the beginning of the Bronze Age of the human history.

On the Balkans, the Bronze Age lasted between the IVth and the end of the IInd millennium BC. The beginning of the Bronze Age is marked by the arrival of some new populations. For us these changes are visible through the introduction of new technologies and the style of ceramics, by the appearance of new home constructions and new types of metal tools as well by the exploration of different copper deposits. A new burial ceremony was established – the construction of tumuli. The Bronze Age is marked by the development of the metallurgy technique starting from almost pure copper, to copper-arsenic alloys or even to true bronze alloy with Sn (concentrations between 3 and 8%) at the late Bronze Age in the IInd millennium. BC. During this age, the ancient smiths mastered the production of silver and lead from Pb-Ag ore. However, the most important achievement of the metallurgy during the IIIrd and IInd millennium BC remains the gradual takeover of the bronze tools in all kinds of everyday work and craft. The production and trade of metals became almost an industrial business where many people were involved.

The Bronze Age could be called also the first "aristocratic age". Before that, only in some exceptional causes such as the Varna Necropolis, individuals who accumulated more goods and power were distinguished. During the IIIrd millennium BC elite societies formed everywhere. Their power was probably related to wars and to trade of rare goods and luxury objects.

The Bronze Age is also the period of the first "international trade" in its direct meaning. The most valuable goods were metals – copper, tin, gold, silver, and lead, which were transported by land and sea in the form of standard ingots. Some valuable gemstones used for ornamental and religious purposes such as lapis lazuli from Afghanistan and amber from the Baltic Sea also travelled long distances in the IIIrd and the IInd millennium BC reaching the Western Mediterranean region and Mesopotamia. The Bronze Age was the time when, besides the trade of raw materials, the trade of objects started: weapons, tools and metal dishes. In the whole area of the Balkans and Central Europe there are weapons found (bronze swords, axes, spear peaks) that are either imported from the Mycenaean Greece or at least are inspired by objects from the Mediterranean region. The dishes of noble metals are the most valuable objects in the Bronze Age. The golden treasure discovered in Valchitran village (Bulgaria) in the 1920s is an example of the highest quality local goldsmith craftsmanship, where the design is strongly influenced by Mycenaean objects. This, undoubtedly ritual, treasure is very valuable (12.5 kg of gold), thus providing evidence of the important ideological role and the great social influence of the ancient priests.

The beliefs and the cults during the Bronze Age were quite different from the ones during the Neolithic–Chalcolithic times. The inhumation burials were done in tumuli. Notables were accompanied to the other world by rich gifts. In the IInd century BC in all areas new megalithic constructions were built that have funeral or cult ritual purpose. The existing social hierarchy in the Bronze Age community is evidenced also by the findings of mountain fortresses that served the local aristocracy and the rulers as residences. The most spectacular and complete information of Late Bronze Age life in the Eastern Mediterranean region is found in the Epic Cycle of Homer treating the Trojan War. These first semi-legendary historical documents made possible the identification of the population of the Bulgarian territory as Thracians. Based on the archaeological continuity it is possible to conclude that the Thracians lived in these lands without any serious conflicts at least in the period IVth–IIIrd millennium BC.

At the end of the IInd millennium BC, the first iron objects appeared and thus the population of the Balkan Peninsula entered the so-called Early Iron Age. Few more centuries ahead, along with the very rare iron objects findings, the bronze tools still remained the preferred ones by the ancient people. Only in the VIII-VIIth century BC the iron becomes the dominating material. The data available on the Thracian tribes during the Early Iron Age (Ist millennium BC) are more abundant and allow identifying some larger dynasty centres related to specific Thracian groups: the Odrysae in Thrace, the Tribals in NW Bulgaria, and the Getae in NE Bulgaria. The archaeological findings and the information provided by the Greek authors allow defining the important and powerful role of the aristocracy in the political and the religious life of the Thracian society. Undoubtedly such important aristocrats and rulers were the ones buried in tumuli like Mezek, Aleksandrovo, Kazanlak, Sveshtari and Starosel. The accumulation of rich treasures such as the Rogozen and the Panagyurishte ones could be explained only as the property of mighty rulers. The power is based on the aristocratic origin of the rulers and their important role in the ritual system of the Thracian society. Here the ruler combined the secular and religious authority into a central function that ensured the order in the Cosmos and the well being of the population. The complex myths and religious rituals, which were sometimes beyond the imagination of today's people, were painted as figural scenes of the frescoes in the tombs and as images on the products of the Thracian artists of toreutics.

The Thracian culture developed at the situation of constant exchange of achievements with the neighbouring tribes who lived on the Balkans. Most fruitful and deep are their relationships with the population of the Greek colonies along the Black Sea coast and the ones on the northern Aegean Sea coast.

The Odrysian kingdom reached its zenith in the period of V–IIIth century BC. During the reign of Teres I (450–431 BC), the Odrysians controlled the lands between the estuary of the Danube River and the catchment area of Tundzha, Arda and Maritsa rivers, and to the east and southeast reaching the hinterland of the Greek colonies. During the reign of Sitalces (431–424 BC), the territory of the Odrysian kingdom expanded to the west reaching the area of the town of Sofia and the valley of Struma River. During the reign of Seuthes I (424–410 BC), Seuthes II (405–391 BC), and Kotys I (384–359 BC), the kingdom further expanded to the Gallipoli Peninsula and the Aegean coast. The fall of the Odrysian kingdom was related to the campaigns of the Macedonian king Philip II (382–336 BC), who expanded its kingdom to the whole southern territory of the Balkan Peninsula, including the Greek polises and the Thracian kingdoms. After the death of Philip II, his successor, Alexander the Great (336–323 BC) strengthened the powers of ancient Macedonia in Thrace and expanded the empire by further campaigning in Persia, Egypt, Mesopotamia, Bactria and reaching the Valley of Ind River in 327 BC. The Empire of Alexander the Great falled immediately after his death and his generals become the rulers of the independent territories of the former empire. In Thrace the successor of Alexander the Great was Lysimachus but soon after the Thracian kingdoms were restored.

Even if very short lived in historical scale, the empire of Alexander the Great greatly influenced all people that were conquered, spreading in their land the ancient Greek culture, fashion and life style and thus Hellenizing them (spread of Hellenistic civilization). Good examples of this period are the Panagyurishte, the Letnitsa and the Rogozen treasures. The name of the greatest Odrysian king in the end of the IVth century BC, Seuthes III (around 330–300 BC), is related to the town Seuthopolis excavated in the 1950s and most likely also to the Golyamata kosmatka tumulus. In the period between the IIIrd and Ist century BC, Thrace was invaded by Celts (invasion in 279 BC) and also suffered from constant dynasty wars. The end of the Thracian kingdoms came in 45 AD, when Rome conquered permanently the land south of the Danube River. At the end of the I[st] century the Balkans were turned into several Roman provinces: Dalmatia, Moesia inferior, Moesia superior, Dacia, Thracia, Macedonia, Achaia and Epirus, which were ruled and developed following the common Roman model. The period between the I[st] and IV[th] century was relatively calm and favoured the fast development of the Balkan towns, prosperity of the agriculture and well-being of the population. The first centuries of the Roman rule was characterised by the process of Romanization: adoption of the Roman way of life and economy; use of Latin language as official written language; and application of the Roman law. The Romanization mostly influenced the townspeople, those living in more isolated and rural areas were less influenced. Archaeological findings and the numerous inscriptions of the Roman Age proved that the population became more and more mixed (by settling of veterans and large groups of people from other parts of the Empire in the lands conquered) and new Mystery religions became important (cult of Mithras and Cybele). In the beginning of the IV[th] century the Roman authority formally ceased the persecution of the Christians: Emperor Constantine issued in 313 the Edict of Milan proclaiming religious tolerance towards Christians. The new religion spreaded fast also among the Balkan population and it was completely Christianized at the end of IV[th] century. Evidences are provided by the findings of impressive basilicas built during that period. One of the most important of these is the St. Sofia Basilica (that also gave the name of the town of Sofia), today located at the city centre of Sofia. The oldest church on the site was built in the IV[th] century and the visible brick masoned basilica was built in the beginning of the VII[th] century by the order of Emperor Justinian, since the old church was destroyed by the Huns and Goths.

In fact these Barbarian invasions from the north by German and Hun tribes lead to the final fall of the Roman Empire. The process could be followed into several stages: in 395 the Roman Empire is divided into Western Roman Empire with Rome as capital (it falls in 476) and Eastern Roman Empire with capital Constantinople. The Eastern Roman Empire (the Byzantine Empire) continued its life until 1453, when the Ottoman Turks conquer Constantinople.

The period of VII–XV[th] century is defined in the historiography of Balkan as Medieval Ages. On the Balkans, it is marked by several closely related processes. On one side the Eastern Roman Empire controlled the southern parts of the peninsula, parts of Anatolia and the Eastern Mediterranean. Even in the VII[th] century, the territory exhibited Greek influence and developed into a specific direction in which the Orthodox Christianity and the will to succeed Rome were the most important issues.

On the other hand, in the period VII–VIII[th] century, large groups of Slavic and Turko-Iranian tribes invaded from the north and settled down on the territory, pushing out the late antique population and creating their own more or less stable kingdoms in the period of the VII–X[th] century. For example the First Bulgarian Empire was created by the Bulgarian Khan Asparuh in 681 after his glorious victory over the Byzantine army. The Medieval Barbarian Bulgarian Empires were experiencing strong influence by the Byzantine Empire that is most of all evidenced by the adoption of Orthodox Christianity by the Bulgarians (Boris I the Baptist in 865), Serbs, Albanians and Romanians.

In the X–XI[th] century, after a series of victorious battles, the Byzantine Empire regained control over most of the territory of the Balkan Peninsula. Important events during that period are the prosperity of the Arab Caliphate, the conquest of Jerusalem by the Muslims and the crusades passing through the Balkans (1[st] Crusade, 1096–1099; 2[nd] Crusade, 1147–1148; 3[rd] Crusade, 1189–1192). During the 4[th] crusade (1202–1204) the crusaders conquered Constantinople and created their own empire in the southern parts of the Balkan Peninsula. The crisis of the Byzantine Empire in the end of the XII[th] and in the XIII[th] century promoted the reconstruction and development of the Second Bulgarian Empire (1185–1396).

In the XIV[th] century the Balkans were invaded by new conquerors. The Ottoman Turks made a successful campaign and conquered Bulgaria (1396) and Serbia (1389–1459). In 1453 Constantinople fell and the whole Peninsula passed under the rule of the Ottoman Empire. Ottoman dominance lasted until the end of the XIX[th] century, when the modern Balkan countries were established following numerous uprisings and wars supported by the European great powers (Habsburg Empire, Russian Empire, British Empire, France): Serbia (1804–1817), Greece (1821–1832), Romania (1859–1878), Bulgaria (1878–1903).

2. Field stops

2.1 Field stop 1. Sofia and The National Museum "Earth and Man"

2.1.1 Serdika – Sredetz – Sofia

(Daniela Stoyanova)

The capital of Bulgaria, the town of Sofia, is located in the Sofia plain, which is surrounded by mountains on all sides – Stara Planina, Vitosha and Lyiulin Mts. The favourable climate and life conditions in this region promoted the createion of human settlements even in the Early Neolithic Age (Stancheva, 1999). A large settlement of this age was excavated in Slatina municipality. Settlements dated from the Chalcolithic, Early Bronze, Early Iron and Hellenistic ages are found in the city centre next to the mineral springs. Impressive finding include the

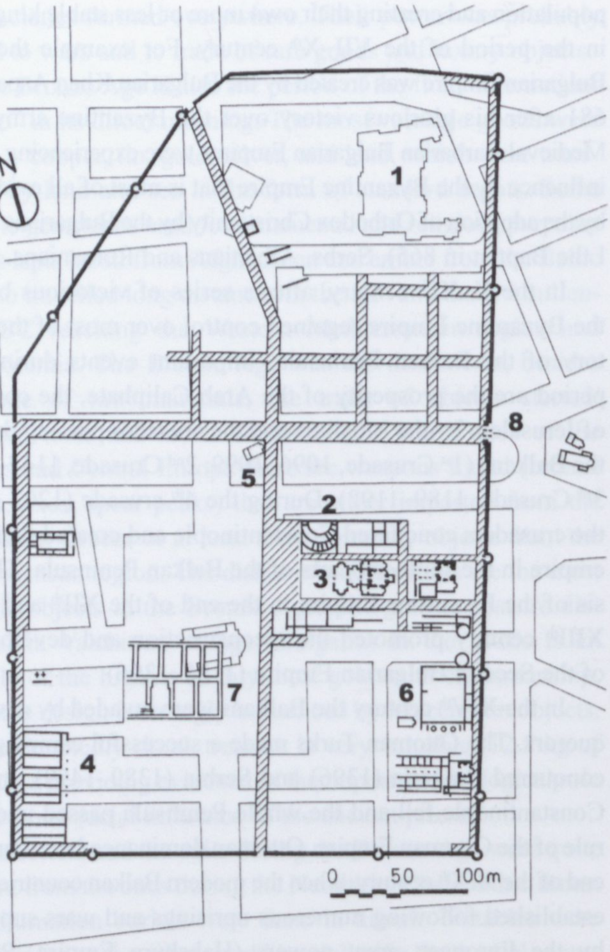

Fig. 11. Late roman and medieval Serdica – Sredets plan.

1 – Roman thermae (bath); 2 – Bouleuterion (Council House); 3 – Rotonda "St – George"; 4 – Three civil basilicas; 5 – The Church of St – Petka Samardjiika; 6 – The church of St. Nikolai Mirlikiiski; 7 – Pretorium; 8 – The East Gate of Serdica.

gold and copper dishes dated as Early Iron Age excavated together with a clay bowl. The gold dish is made of high purity gold. Only two more dishes of the same time period are known to have been found in Bulgaria.

The area was populated by the Thracian tribe Serdi and the first findings about them are dated to the period when Rome fought for the conquest of their lands. In 29 BC the lands of the Serdi were invaded for the first time by the Roman legions led by the head of the Roman province of Macedonia, Marcus Licinius Crassus. Soon after that the whole territory of the tribe was included in the territory of the Roman Empire. In the beginning, the city was the centre of Serdica strategy. The name of the strategy was used later as the name of the city itself as well as the name Serdonpolis. During the reign of Emperor Trajan (98–117) Serdica obtained urban rights. The town is mentioned in many inscriptions and also on coins from the reign of Marcus Aurelius as Ulpia Serdica. Around 270–272 the province Dacia Inferior was created and Serdica was its capital city.

The fortress wall is one of the most important Roman constructions so far excavated. The period when it was built is well known from one inscription preserved in two copies. It says that the name of the city is Serdonpolis and it was founded during the reign of Emperor Marcus Aurelius (176–180). The fortress walls (Fig. 11) form a frame that had surrounded a large area for many centuries until it was finally destroyed in the XVth century by the Ottoman Turks invasion. The area surrounded by the wall gradually became too small and many important buildings, including several temples, were placed outside this area. The wall served and area of about 164 000 m^2 and was built of bricks on a socle (wall base) made from two rows of stone blocks (Fig. 12). It was about 8–9 m high and 2.2 m thick.

Fig. 12. The fortress wall of Serdica (Sofia) town restored and exhibited in the subway in front of the President's Office (photo: V. Kovachev)

Every 50–60 m along its whole lenght, round towers were built, their height exceeding by 2–3 m the height of the wall itself. The main entrance was made entirely of regular stone blocks. The Forum of Serdica is located in the centre of the modern city, under today's St. Nedelya square. To the south of the Forum there was the Pretorium (Fig. 11). This was the most important public building, which was destroyed at the end of the Age of Antiquity. It was replaced by church area in the Xth or in the XIth century.

The City Council (Fig. 11) is another excavated building. There is an interesting marble relief found in this building, which is decorated by images of the different amusements found in the city. Another building excavated is the Gerousia. To the south of it, almost at the southern fortress wall, the remnants of another three civil basilicae are located (Fig. 11). The thermae (mineral baths) took vast area in the northeastern quarter of the city, where today the Central Sofia Spa is located (Fig. 11). Parts of the Roman thermae were used even in the XVIIIth century. The existing data show that the City Council and the thermae buildings were destroyed by an earthquake.

The inscriptions and the sculptural decorations found in Serdica and the surrounding area attribute to the existence of many cults besides the traditional Thracian ones and the most important of them – the Heros – the Thracian Horseman (Fig. 13). Other cults at that same time were to Zeus, Apollo, Artemis, Asclepius and Hygieia, Aphrodite, Dionysus,

Fig. 13. Thracian horseman. Image on marble. Subway in front of the President's Office (photo: V. Kovachev)

Athena, Tyuhe, Sarapis, Cybele, Mithra, Hercules, Hermes, Three Nymphs, Nemesis, Hecate, Selena, Eros. The temples of Asclepius and Appolo Medicus, Artemis, Hypsistos, Sarapis and Hercules have been excavated.

In the Age of Antiquity, to the southeast of Serdica, a manufacture of construction ceramics was organized – brick kilns are found near clay deposits. Stonework and production of iron were also organized in the areas closer to the Vitosha Mountain and continued their development until Late Medieval Age. In the areas closer to Serdica there are no copper deposits. However, during teh Antiquity or even before that, the Neogene and Paleogene lake and river sediments were mined for gold. The most interesting find related to the production of gold in Serdica are the galleries found in the modern Darvenitsa municipality. The galleries are about 1.20–1.30 m high and 0.35–0.50 m wide.

The life of the city changed considerably in the IV[th] century. During the the first decade of the fourth century, Emperor Constantine the Great (306–337) was a frequent guest and this led to many reconstruction activities in the southeastern parts of Serdica. A new city, the Emperor's palace and related buildings were built. This monumental complex included also the Rotunda "St. George" (Figs. 11 and 14). This is the only architectural find in Sofia that survived the time since the IV[th] century as a whole building with its roof. The Rotunda is 9.75 m in diameter and reaches 14 m at the highest parts of the dome. It became a Christian church as early as the VI[th] century.

Fig. 14. The Rotunda "St. George" (photo: D. Taneva)

The Necropolis of Serdica was located in a vast area outside the city walls covered with stone and humble graves with tiles. As funeral constructions and monuments were used tumuli, stone sarcophagi, and tombs made from bricks. Since the IV[th] century, distinguished citizens started to build large masonry vaulted tombs, sometimes designed for whole families. Until today, about 15 tombs decorated with paintings are excavated. In the same period, the construction of many churches also began. In 343 the famous Council (Synod) of Serdica took place in one of them. The churches gave the city a new look. The civil architecture was governed by the masonry style and was dominated by the large and solid volumes of the basilicas.

In the VI[th] century, probably under the reign of Emperor Justinian I (527–565), a new city wall was built 20 m away from the first wall. During the same period the constructions in the city also expanded and became denser. The large streets were partially covered by the new extensions of the buildings. Often the extensions represented shops and workshops, possibly related to residential premises.

Fig. 15. The church "St. Sofia", that gave the name of Sofia city (photo: V. Kovachev)

Also during the reign of Justinian I one of the most remarkable architectural objects was built and remains until today – the Church of Hagia Sophia (Fig. 15). Its design includes a narthex (lobby), three aisles, a transept and a dome. The length of the building is 46.45 m and the width of the transverse part is 20.20 m.

Today it is marked by its thousand years of life of many dramatic changes that led to changes in its look. On its both sides, there were towers taller than the narthex that contained the staircases to the three floors. The major premise of the three parts of the basilica was under one roof and the side parts had galleries that were destroyed during the Medieval Age. The transept forms the central part of the basilica as the longer vertical part of a cross. On the arches and pendant in the centre of the cross lies a low drum, covered with a dome. Its diameter is 9 m and its height from the floor to its zenith is about 20 m. The apse is of three walls. The facade is decorated only by the large windows with arches. The internal space is divided by two rows, each containing six massive pillars. There is information that in the Medieval Age the basilica had murals on the walls that were later destroyed when the church was converted into a mosque. Under the floor of the church several tombs of the Late Antiquity Serdica Necropolis are preserved.

In 809 Serdica became part of the newly found First Bulgarian Empire and received a new name – Sredets. The city walls, entrances, streets, water and sanitation pipes that were built in ancient times continued to be used and maintained. During the Medieval Age the city represented an important strategic centre and was known as a fortress that could not be conquered. After the 1018 the city fall under the Byzantine rule.

The Rotunda St. George was covered by mural paintings three times during the rule of the First and of the Second Bulgarian Empire. In the XVIth century the church was converted into a mosque and all the murals were covered by new plaster layer and by Muslim inscriptions. In the Medieval city, free spaces were few and not very large. As a result, the newly built churches were very small and densely distributed in its central parts – Old "St. Petka", "St. Nicholas the Wonderworker" (Fig. 11), "St. Petka of the Saddlers" (Figs. 11 and 16), "St. Spas".

Fig. 16. The church "St. Petka of the Saddlers" (photo: V. Kovachev)

The city of Sredets is related also to the name of an important member of the Bulgarian aristocracy – Sebastokrator Kaloyan, cousin of Tsar Constantine Assen (1257–1277). Its name is famous from an inscription in Boyana church (Fig. 17), UNESCO protected site, found close to the portrait of Kaloyan and its wife Dessislava, who were donators of the church.

Fig. 17. Boyana church (photo: V. Kovachev)

The church was painted in 1259. The second or the Kaloyan part of the church occupies its western parts. The building has two floors. The murals on the first floor are almost entirely preserved. The Boyana church also contains the largest well-preserved fresco scene from the XIIIth century, which is a precious monument of the medieval art in the whole Orthodox world.

In the middle of the XIVth century, Sredets has been renamed to Sofia after the Church of Hagia Sophia. Its imposing silhouette rose on the height east of the old city and gradually became famous as his symbol. In 1378 the city was called Sofia for the first time in a legal Bulgarian document: the charter issued and gold stamped with the personal seal of Tsar Ivan Shishman regarding the rights and the possessions of the Dragalevtsi monastery.

In 1382 Sofia was invaded by the Ottoman Turks. In 1443 it was liberated for a short period of time by the Hungarian army led by János Hunyadi. In the administrative structure of the conquered lands, Sofia was the centre of a vast territory of Rumelia beylerbeylik (province). The Church of Hagia Sophia was transformed to a mosque. In the XVth century the biggest mosque in Sofia was built and remained until today – the Buyuk (Great) Mosque (Fig. 18). In 1503 next to the Konak (governor's residence) another mosque was build – the Chelibi Mosque. In the XVIth century many other mosques were built and the city obtained an oriental look. The famous building of the so-called Banya Bashi Mosque (Great Mosque of the Baths) built in 1575 has been functioning until today. Its large dome is decorated on the outside by fine semi-arcs. It was con-

Fig. 18. The Great Mosque (photo: V. Kovachev)

structed by the famous Turk architect Hadji Mimar Sinan. The mosque Kodja Dervish Mehmed Pasha, built in 1528 (called The Black Mosque), also preserved its original architecture and features until our time, although it was transformed into a Christian church in the XXth century.

Fig. 19. Architecture of Sofia city during XIXth and XXth century (photo: V. Kovachev). The Konak (former Turkish residence) reconstructed into King's Palace after the Liberation, at present National Art Gallery (up); The St. Alexander Nevski Cathedral (down).

After the XVth century and before the end of the Ottoman Rule in 1878, many Orthodox monasteries were reconstructed and they were important places of social and cultural life of Sofia: these are the Dragalevtsi, Kremikovtsi St. George, Kurilo St. Ivan Rilski monasteries among many others.

In 1879, the town of Sofia was chosen for the capital of the Third Bulgarian Kingdom (Fig. 19, on up). In the end of the XIXth and in the beginning of the XXth century, a new reconstruction period led to the modern European look of the capital today. During this period, the buildings of the National Assembly (1884–1886), the National Theatre Ivan Vazov (1906), the Alexander Nevski Cathedral (1912) (Fig. 19, down), and the University of Sofia (1934) had been erected.

Fig. 20. The arena of Serdica exposed in the foundations of the newly built hotel "Arena di Serdica" (photo: V. Kovachev)

The construction of new buildings continues also today and greater attention is paid to the incorporation of the historical buildings into the modern look of the city.

2.1.2. The National Museum "Earth and Man" (Mihail Maleev)

The Earth and Man National Museum (EMNM) is a museum of the mineral kingdom, which contains 25,366 items (by January 1, 2009). Seven permanent expositions show 3875 of these as follows: Giant Crystals, Minerals of the Earth, Mineral Resources of the Earth, Mineral Resources of Bulgaria, Minerals of Bulgaria, Gems and Ornamental Stones, Materials. The museum possesses 1447 mineral species from 104 countries thus representing ~30% of the mineral species discovered on the Earth. The museum preserves mineral raw materials from more than 700 deposits of 81 countries (Fig. 21), a diversified collection of gems and gemstones, the most complete collection of Bulgarian minerals, regional and scientific collection.

The Earth and Man National Museum is a state institution affiliated to the Ministry of Culture in Bulgaria. The museum was founded on January 1, 1986 and was opened to the public on June 19, 1987.

Fig. 21. Azurite, porphyry copper deposit Vlaikov vrah, Panagyurishte ore region

Private persons, companies and institutions gave all the funds for creating the museum and for acquiring the mineral samples through The National Donation Fund “13 Centuries of Bulgaria”. 840 donors including 221 companies and state institutions and 619 persons from all over the world have been registered as contributors at the museum.

The museum is located in the downtown of Sofia in a restored building – a cultural heritage protected building from the end of XIXth century (Fig. 22). Its functionally reconstructed 4000 m^2 area houses exhibition halls, depositories, laboratories, a video hall and a conference room. The reconstruction project was prepared by the architect Hristo Ganchev. The artist Ivan Radev made the interior design, the original murals in the museum hall were painted by Theophan Sokerov (Fig. 23).

Fig. 22. The building of the National Museum „Earth and Man” constructed in the end of the XIXth century

Fig. 23. Mural painting „Earth and Man”, artist Theophan Sokerov

According to its special field, the Earth and Man National Museum covers a wide variety of the facets of mineralogy: life and environment, raw material and energy sources, subject of scientific knowledge, and object of emotional and aesthetic impact. Considering the different aspects of the mineral kingdom, the Earth and Man National Museum is attractive to large social groups such as geologists, miners, scientists, technologists, ecologists, artists, business persons, collectors, students and children. The museum attracts about 80 000 visitors in a year.

The museum also carries out research in five laboratories: X-ray analysis, optics, physical properties of minerals, thin section (sample preparation), computer lab. The museum also includes a library, a multimedia room, scientific archives, and a photo studio.

The National Museum “Earth and Man” hosts many traditional activities, as for instance the annually organized events the Earth Day – April 22 (since 1990), the International Competition for Instrumentalists and Composers “Music and Earth” (since 1993), the International Photographic Contest-Exhibition “Earth for All”, the National Scientific Competition “The Earth – Known and Unknown”. Day of mineral diversity, Days of minerals, Day of donors and Day of compassion.

2.2 Field stop 2. Chelopech massive sulphide Cu-Au mine

(Strashimir Strashimirov, Veselin Kovachev & Veselin Mladenov)

General

Fig. 24. General view of Chelopech deposit from the south

The Chelopech high-sulphidation type epithermal massive sulphide Cu-Au deposit (Fig. 24) is a part of the Elatsite–Chelopech ore field, which is located in the northernmost parts of the Panagyurishte ore region (Fig. 7 and Fig. 25). Although both deposits, Elatsite and Chelopech, are situated in the Stara Planina Mountain (Elatsite – on the northern slope, and Chelopech – on the southern one) their features indicate that they belong to the Srednogorie metallogenic zone. The underground mine is located about 70 km east of the city of Sofia, at the western end of Chelopech village. The deposit was prospected after World War II and the production started in 1953. Until 1990 the concentrate produced was treated in the Pirdop smelter, a few km east of the deposit, where conclntrates were mixed with those from the other copper deposits in the Srednogorie zone. The higher As content in the Chelopech concentrates, due to the high amount of enargite, tennantite and other As-bearing sulphosalts minerals, lead to serious ecological problems in the area around the smelter. From 1990 to 1993 the mine was out of production. In 1993 it was privatized by the Navan Resources Ltd and the concentrates produced were treated abroad. In the period 2003 to 2009 a total of 4.8 Mt ores with 1.42% Cu and 3.99 g/t Au were mined from Chelopech mining JRS and the remaining resources are estimated to be at about 20 Mt.

The position of the Chelopech deposit in the Elatsite–Chelopech ore field is controlled by the Upper Cretaceous volcano-plutonic complex of the same name (Fig. 26). It includes several early formed subvolcanic to hypabyssal minor intrusions, the later Chelopech volcano and subsequent subvolcanic to subvolcanic-hypabyssal intrusions. The deposit is located in the central part of the volcano-plutonic structure.

The basement of the volcano-plutonic complex consists of Precambrian metamorphic rocks including granite-gneiss, two-mica schist, quartzite, amphibolite, etc., exposed south and east of Chelopech village. The metamorphic basement is covered by Permian terrigenous volcanics and a terrigenous and transgressive shallow-marine succession of Triassic, Jurassic and Upper Cretaceous age.

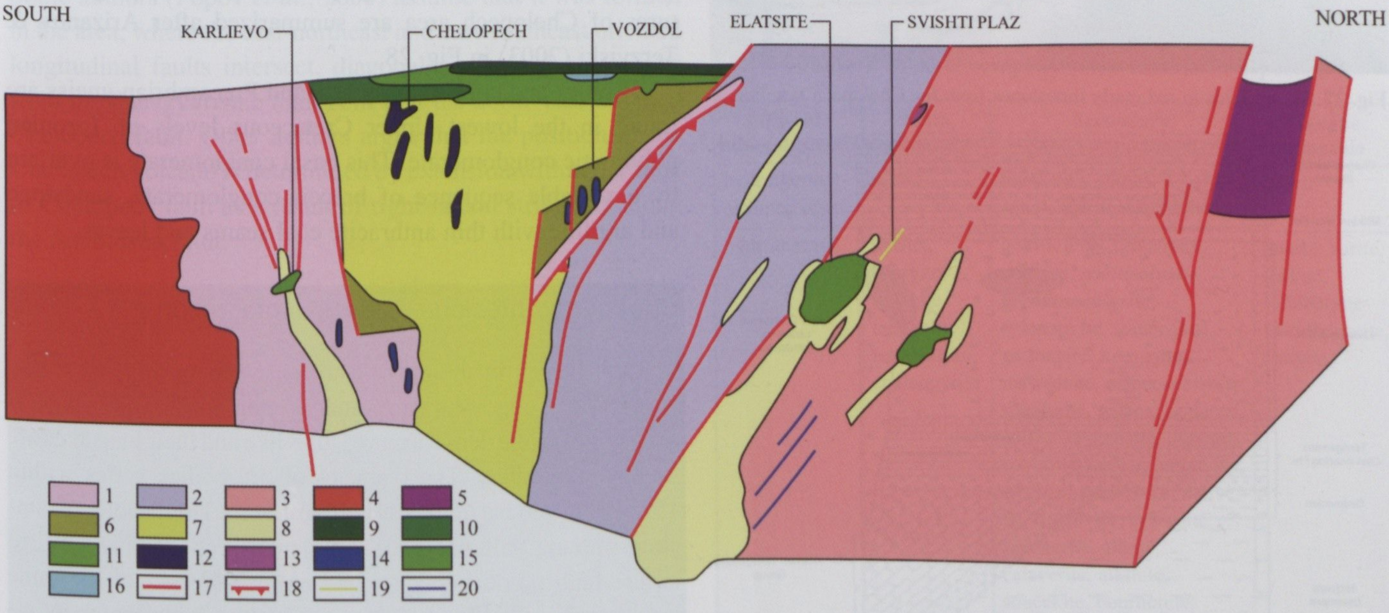

Fig. 25. Schematic geological cross-section of Chelopech ore field

1 – Metamorphic rocks (undivided Arda Group); 2 – Phyllites, hornfelses (undivided Berkovitsa Group); 3 – Granodiorite (Vezhen pluton); 4 – Srednagora granites; 5 – Triassic & Jurassic sediments; 6 – Turonian conglomerates & Sandstones; 7 – Subvolcanic dacites/andesites; 8 – Monzodiorite porphyrites; 9 – Flysch; 10 – Polymict sandstones; 11 – Post-ore volcanic breccias; 12 – High-sulphidation epithermal ore bodies; 13 – Base metal / barite bodies; 14 – Gold / base metal veinlet zones; 15 – Porphyry Cu-Mo ores; 16 – Si-Fe-Mn mineralization; 17 – Fault; 18 – Overthrust fault; 19 – Gold / pyrite vein; 20 – Barite / base metal vein

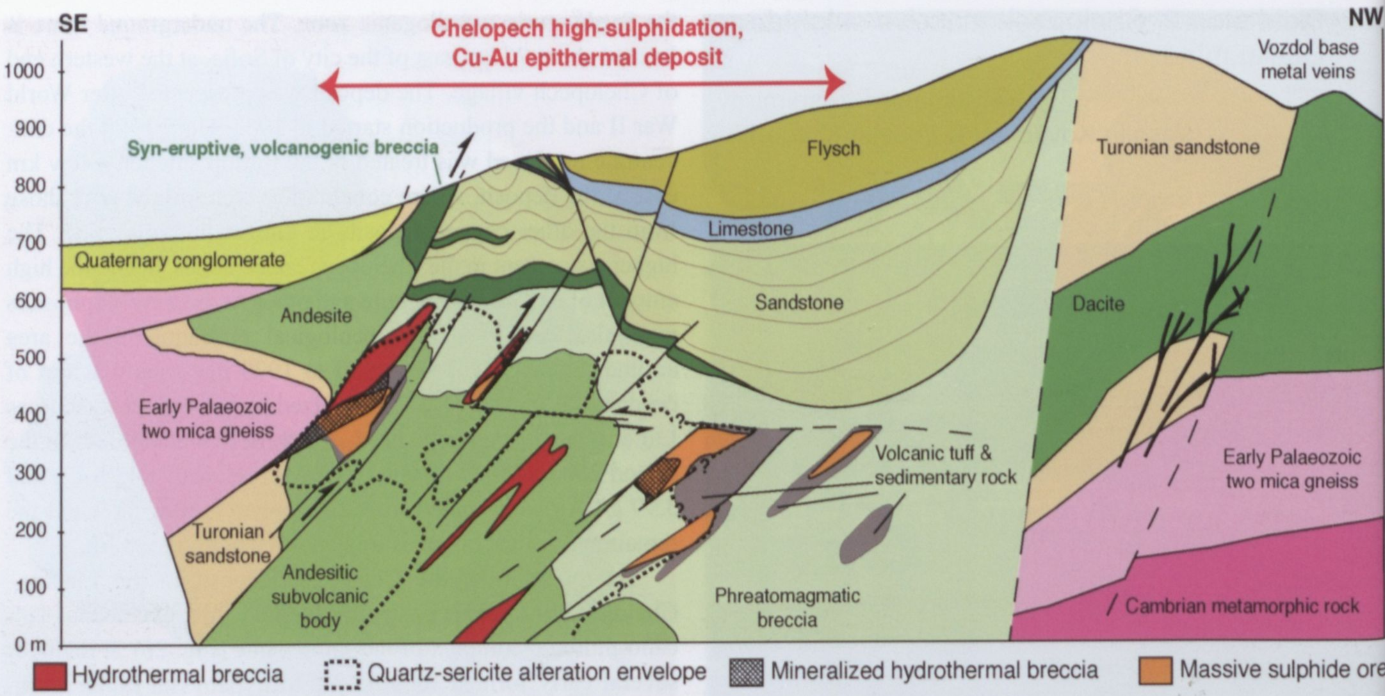

Fig. 26. Cross-section through the Chelopech deposit based on surface and underground mapping, extensive drillcore descriptions and observations, and including information from Popov and Kovachev (1996) for the north-western part at Vozdol. Rock units are Late Cretaceous, unless stated otherwise.

Fig. 27. Slump folds in red marly limestones from the Chelopech syncline

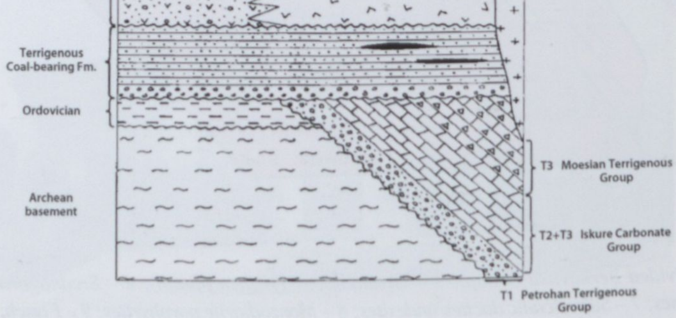

Fig. 28. Lithostratigraphic column of Chelopech region (after Arizanov & Terzyiski, 2003)

The ore mineralization is localized in the Upper Cretaceous Chelopech Formation, which includes a basal clastic sedimentary stage, a lower mineralized volcanic stage and an upper post-mineralization stage, which are separated by unconformities. The ore-hosting rocks include siliciclastics, volcanics and volcaniclastics. Post-ore rocks are sandstones, red marly limestones (Fig. 27), flysch-type calcareous turbidites and oreclasts, which form the Chelopech syncline (Fig. 26).

The schematic lithostratigraphic and geochronological features of Chelopech area are summarized after Arizanov & Terzyiski (2003) in Fig. 28.

Pebbles and cobbles of quartz and Precambrian gneiss are found in the lowest Upper Cretaceous levels of Turonian polymictic conglomerate. This basal conglomerate is overlain by a variable sequence of breccia-conglomerate, sandstone and argillite with thin anthracite coal seams and lenses.

Copper and precious metals mineralization

The ore bodies in the deposit are localized in three sectors – "Central", "Chugovsko dere" and "Sveta Petka". Their shape is mainly stock-like, lense-like and tube-like and their long axes are usually subvertical. The diameter of ore bodies varies within 150–400 m and the thickness is 20 to 120 m. This enables to construct mining galleries with large cross-sections (Fig. 29), to ensure high production rates and motor transport of the mine products (Fig. 30). The large cavities in the mining chambers are filled with waste products from the processing plant. The host rocks are mainly agglomerate and lapilli tuffs, rarely lava flows. The ore bodies are related in most cases to the exocontacts of subvolcanic intrusions, necks and diatremes (Popov *et al.*, 2000)

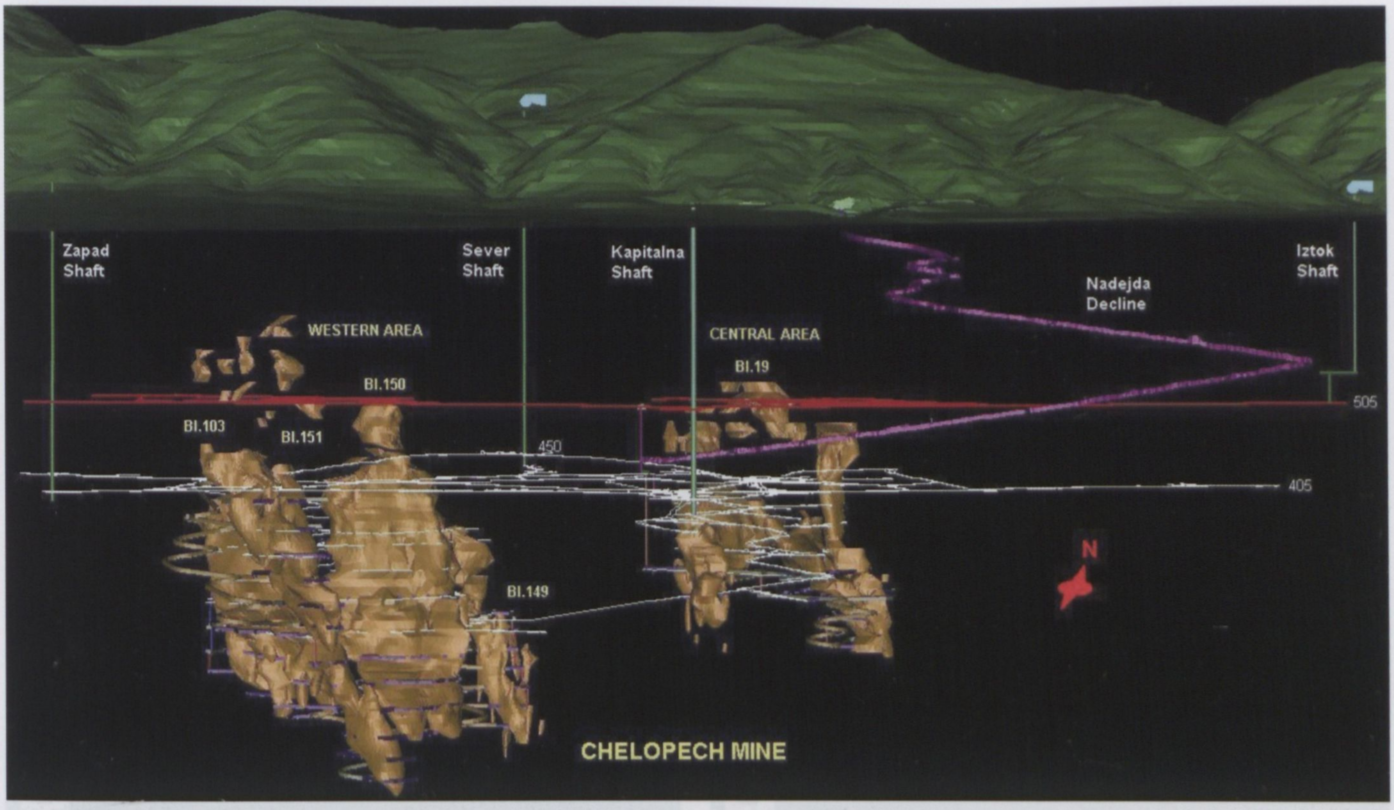

Fig. 29. Morphology of ore bodies and general exploitation scheme of Chelopech deposit (3D model)

The Chelopech volcano is located in the central part of the ore field, to the north and west of the village of Chelopech (Fig. 26). The thickness of the volcano cone is over 1200 m in the central part and about 700–800 m in the marginal parts. The southern and eastern parts of the cone are uplifted and erroded.

The origin of the Chelopech volcano is under discussion. Some authors (Popov *et al.*, 2000) assume that it was formed in the area, where the east-northeast and east-southeast oriented longitudinal faults intersect, diagonal north-northwest faults from the Panagyurishte fault zone and the north–east oriented Chelopech fault. Other authors argue that the position of the Chelopech volcano is determined by extension within the zone of Chelopech fault as a result of right-lateral strike-slip along the Subbalkan fault.

Fig. 30. Transport galleries and mining blocks in Chelopech deposit (photo: K. Dimitrov)

The mineral composition of the deposit is extremely rich (Table 4) and includes a number of minerals-carriers of elements like Cu, Fe, As, Sb, Te, Bi, Se, Sn, Mo, Ge, Au, Ag, Pb, Zn, Cd, V, Ga, Hg. The depost is famous as a locality for the first finding of some minerals such as kostovite, hemusite (Terziev, 1968), stibiocolusite and germanocolusite (Spiridonov *et al.*, 1992a, 1992b).

Table 4. Mineral composition of Chelopech deposit

Type of mineral genesis	Main minerals	Secondary and rare minerals	Gangue minerals
hydrothermal-sedimentogene	pyrite	marcasite, galena, sphalerite, chalcopyrite	quartz
hydrothermal	pyrite, enargite, luzonite tennantite–tetrahedrite, chalcopyrite	goldfieldite, famatinite, colusite, ***stibiocolusite***, ***germanocolusite***, nekrasovite, stannoidite, germanite, **hemusite**, mawsonite, arsenosulvanite, sphalerite, galena, renierite, gallite, chalcocite, digenite, covellite, anilite, native Au, electrum, native Te, native Bi, **kostovite**, sylvanite, krennerite, altaite, calaverite, aikinite, součekite, bournonite, eucairite, clausthalite, kawazulite, petzite, colarodoite, nagyagite,	quartz, barite, dickite, svanbergite–woodhouseite, zunyite

Chelopech is the type locality of minerals **in bold** and co-type locality of minerals ***in bold italics***.

Ore mineralization formed during the first hydrothermal-sedimentary stage is of rather restricted distribution and of no economic value. It is represented by ***pyrite–marcasite association*** including fine-grained pyrite, pyrite–marcasite aggregates with colloform structure or compact masses of fine-grained pyrite and chalcedony-like quartz. These minerals were formed on the bottom of a basin as a result of mixing of low temperature hydrothermal brines and seawater (Petrunov, 1995; Popov & Kovachev, 1996).

The main economic ores in the deposit were formed during the hydrothermal stage and occure mainly in the central part of the deposit as massive aggregates, accompanied by disseminations, fine impregnations and nests. Minerals formed during this stage can be divided into five different associations – pyrite–chalcopyrite, enargite, tennantite, galena–sphalerite and carbonate–anhydrite ones. The last two are much more typical for the marginal parts of ore bodies and the deposit in general.

Pyrite–chalcopyrite association was formed during the initial stage of the hydrothermal ore-bearing processes. It has limited distribution in the deposit and includes mainly pyrite and less calcopyrite in the form of nests or disseminations.

Enargite association (Fig. 31) is one of the main economic associations and includes mineral phases of the Cu–Fe–S (pyrite, bornite), Cu–As–S with Sb, Te, Bi (tennantite–tetrahedrite, goldfieldite) and Cu–Fe–Sn–S with Mo, Ge, and V (stannoidite, colusite, hemusite, germanite, stibiocolusite and germanocolusite) systems. Minerals from this association were formed simultaneously or within a narrow period of time, which is indicated by numerous zonal polymineral aggregates containing usually several from the above-mentioned phases.

Tennantite association includes minerals from the Cu–Fe–S (pyrite, chalcopyrite, bornite), Cu–As–S±Te (tennantite and Te-bearing tennantite, and Cu–Fe–Sn–S (mawsonite and arsenosulvanite) systems. This association also contains minerals from very different geochemical systems such as Cu–Pb–Bi–S–Se (aikinite, součekite, wittichenite, clausthalite, native Bi), Pb–Bi–Hg–Te–Se (altaite, tellurobismuthite, kawazulite, native Te, coloradoite) and Cu–Au–Ag–Te (kostovite, sylvanite, calaverite, krennerite, petzite, native Au and electrum) developed mainly in the upper parts of the deposit. In association with bornite, gold aggregates ranging in size up to 1 cm have been found (Kovachev *et al.*, 1988). This association is

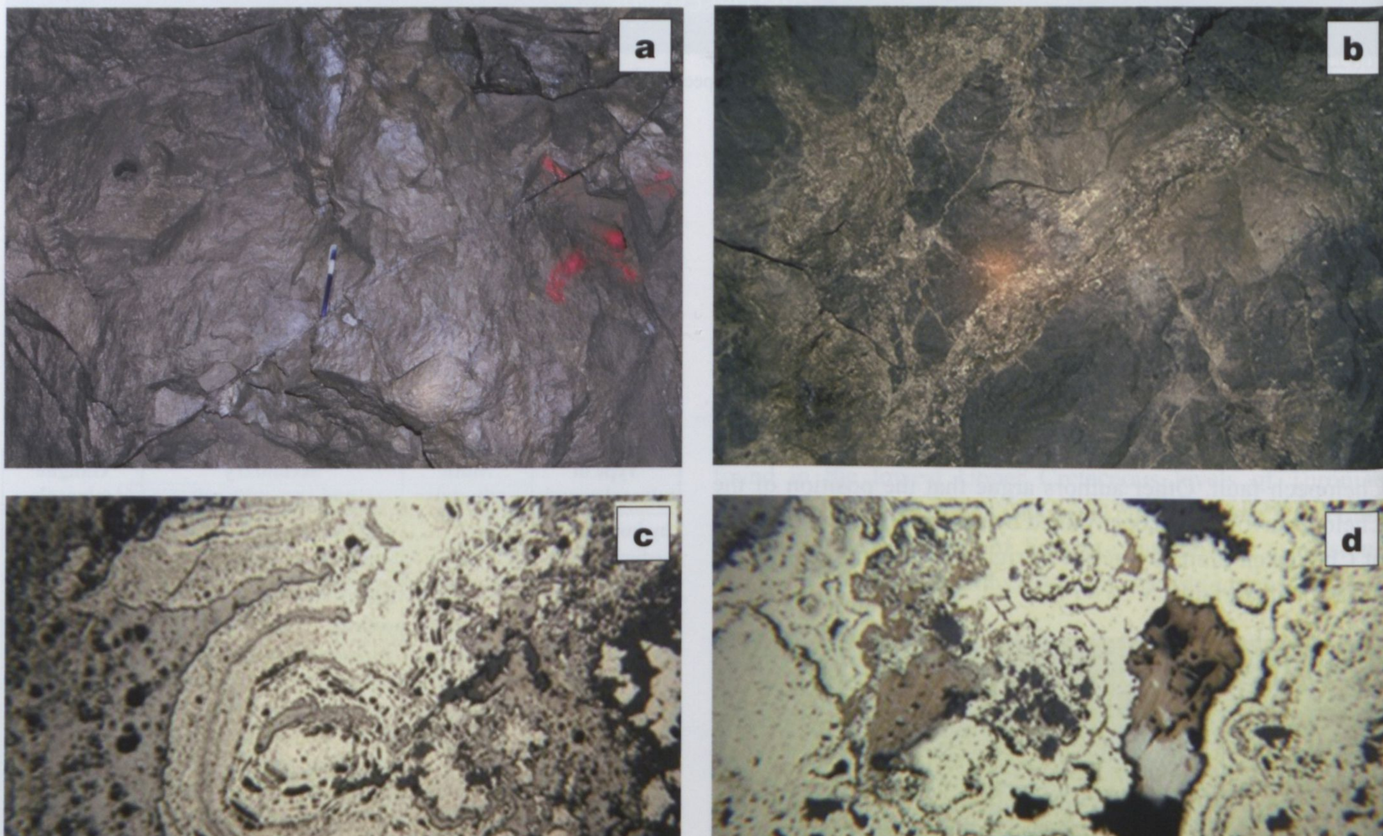

Fig. 31. Ore types in Chelopech deposit (photos: K. Dimitrov and V. Kovachev)

a) pyrite–enargite–tennantite massive ore type; b) vein-like pyrite–chalcopyrite ore type; c) crust-like aggregates of pyrite with higher As content and enargite–bornite mineralization; d) pyrite, kidney-shaped aggregates (light yellow), encrusted by Cu-As sulphosalts (light grey) and bornite (brown)

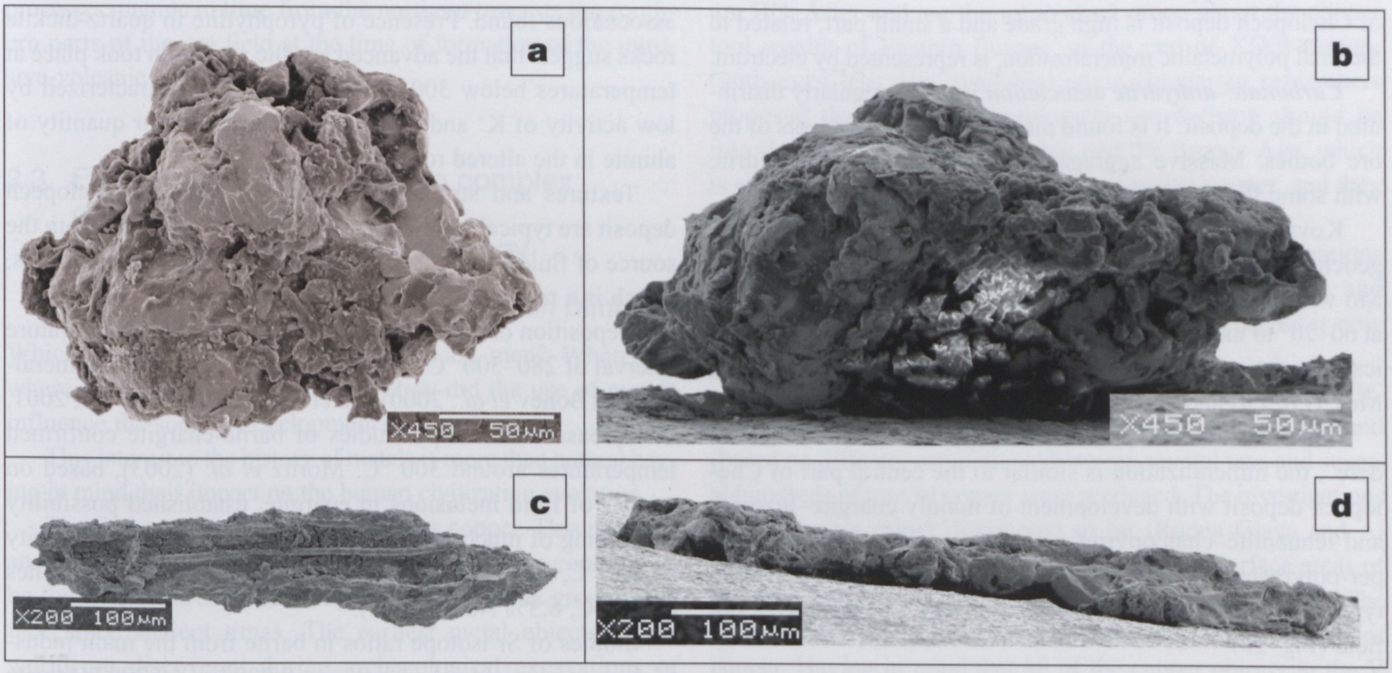

Fig. 32. Morphology of gold aggregates in rivers and streams in direct proximity to ore bodies (up to 1 km) in Chelopech deposit
Isometric (due to mechanical reworking during transport in exogenic environment) gold aggregate – view from two mutually perpendicular directions (a and b); dendrite-like gold aggregate with relatively well preserved primary form – view from two mutually perpendicular directions (c and d)

the main carrier of industrial gold. According to the studies of Kovachev *et al.* (2007) it is high-grade (950‰) with admixtures mainly of Ag (up to 3,5%), Cu (up to 1,5%) and Fe (up to 0,5%). Part of the elements in the latter geochemical system occurs as trace elements in the main minerals from the enargite association (Se in bornite and enargite, Bi, Au and Ag in goldfieldite and others). In this sense, part of the newly formed minerals could be accepted as product of recrystallization and mobilization of elements from earlier formed associations. It should be emphasized that the tannantite association is the main carrier of gold in the deposit.

Galena–sphalerite association was formed in the end of the ore-forming processes. It contains fine-grained aggregates of galena and sphalerite accompanied by minor quantity of tennantite and chalcopyrite. Native gold in this association is of lower grade (in average 806‰), the highest Ag content being about 19% and that of Cu and Fe are below 1% (Kovachev *et al.*, 2007). The main gangue mineral is barite, while quartz is very rare. The association is developed in the marginal parts of the ore bodies and is most typical in the upper parts of the deposit. It overlaps earlier formed associations and in some sectors forms well shaped veins.

Gold in Chelopech deposit is one of the main industrial components. Recent studies on placer gold in rivers and streams in direct proximity to outcrops of ore bodies (distance up to 1 km) show that the mechanical deformations during the exogenic process are considerable, despite the short transport distance. Based on the morphometry of gold aggregates it was established that secondary-isometric aggregates predominate (Fig. 32a–b), whereas aggregates with preserved primary dendritic form (Fig. 32c–d) are relatively rare.

Microprobe studies confirm the presense of predominantly high-grade gold and subordinate quantity of electrum. There are three frequency maxima of gold content in gold aggregates (Fig. 33). The first (main) maximum, including 67% of the analyzed samples, is between 90 and 98% Au and the next two small maxima are at 80% Au between 60 and 72% Au in gold aggregates (17% of all samples). These data show that the alluvial gold contains higher Ag quantities in gold aggregates as compared to gold in primary ores.

Based on the random distribution of the studied gold aggregates in rivers and streams in the area of the deposit, it can be concluded that the main form of occurrence of gold in the ores

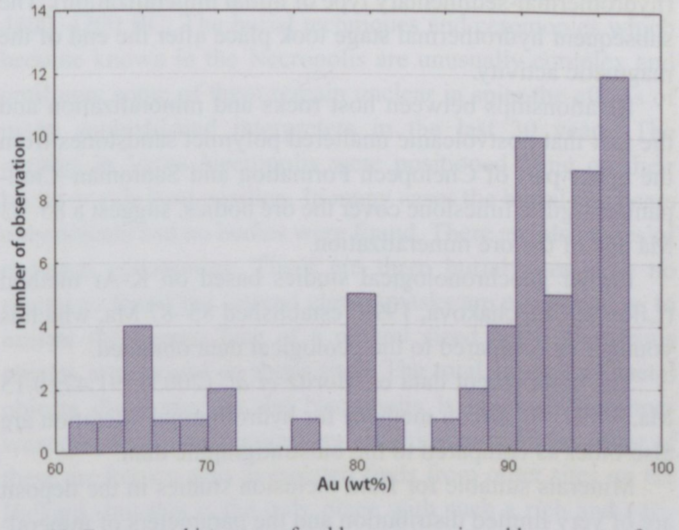

Fig. 33. Frequency histogram of gold occurrence in gold aggregates from rivers and streams in direct proximity to ore bodies in Chelopech deposit (based on 60 microprobe analyses).

of Chelopech deposit is high grade and a small part, related to the final polymetallic mineralization, is represented by electrum.

Carbonate–anhydrite association is very irregularly distributed in the deposit. It is found mainly in the upper levels of the ore bodies. Massive aggregates of carbonate and anhydrite with some fluorite are typical of the deeper parts.

Kovachev *et al.* (1992) established well-outlined primary geochemical aureoles of Cu, Pb, Zn, As, Ba, Ag, Co, Ni and Mo with elipsoidal shape in vertical direction and inclination at 60–70° to the south. These authors distinguished 3 geochemical associations of elements-indicators of ores (Cu, As, Ag, Ba, Mo), (Pb, Zn) and (Co, Ni).

In the easternmost parts of the deposit, known as "Charlo dere", the mineralization is similar to the central part of Chelopech deposit with development of mainly enargite–luzonite and tennantite–chalcopyrite associations. The "Vozdol" copper-polymetallic mineralization of impregnated, non-payable type is localized in the northeastern part of Chelopech ore field (Fig. 25).

Hydrothermal alteration

The hydrothermal alteration in the Chelopech deposits have been studied by many authors: Radonova (1969, 1970); Moutafchiev & Chipchakova (1969); Radonova & Velinov (1974); Chipchakova (1974); Chipchakova *et al.* (1981); Lilov & Chipchakova (1999); Simova *et al.* (2001) and others.

Numerous studies published in the last years, classify Chelopech deposit as a representative of high-sulphidation (acid sulphate) type epithermal deposit (Petrunov, 1994, 1995; Arribas, 1995; Petrunov *et al.*, 1997, 2000; Popov *et al.*, 2000; Simova *et al.*, 2001; Chambefort *et al.*, 2002; Jacquat *et al.*, 2002; Bonev *et al.*, 2002; Moritz *et al.*, 2002, 2003).

The so far obtained data suggest that the ore mineralization was formed during a relatively broad time interval. Mineralization started at the same time as the effusive activity (hydrothermal-sedimentary type of initial mineralization). The subsequent hydrothermal stage took place after the end of the magmatic activity.

Relationships between host rocks and mineralization and the fact that postvolcanic unaltered polymict sandstones from the upper part of Chelopech Formation and Santonian–Campanian argillic limestone cover the ore bodies, suggest a 85–83 Ma age of the ore mineralization.

Earlier geochronological studies based on K-Ar method (Lilov & Chipchakova, 1999) established 85–87 Ma, which is younger as compared to the geological data obtained.

The most recent data of Moritz *et al.* (2003) (91.47±0.15 Ma, $^{206}Pb/^{238}U$ zircon method) for hydrothermal alteration are also older as compared to the biostratigraphic data.

Minerals suitable for fluid inclusion studies in the deposit are of very limited distribution and the parameters of mineralization system could be determined on the basis of the mineral associations found. Presence of pyrophyllite in quartz-dickite rocks suggest that the advanced argillic alteration took place at temperatures below 300 °C. The process is characterized by low activity of K^+ and SO_4^{2-} confirmed by minor quantity of alunite in the altered rocks.

Textures and structures of ores observed in Chelopech deposit are typical of mineral associations formed far from the source of fluids. Colloform structures are often found in ores, which is a result of colloidal type of brines.

Deposition of coarse-grained enargite marks a temperature interval of 280–300 °C for precipitation of economic mineralization (Bonev *et al.*, 2000). Later studies (Moritz *et al.*, 2001, 2003) based on isotope studies of barite-enargite confirmed temperatures around 300 °C. Moritz *et al.* (2003), based on studies of fluid inclusions in enargite, established possibility for mixing of much hotter brines with relatively high salinity (> 221 °C, 20.4% NaCl equiv.) with cooler and diluted brines (<175 °C, 6.3% NaCl equiv.).

Studies of Sr isotope ratios in barite from the main industrial ore stage yield values between 0.7077 and 0.7087 (Moritz *et al.*, 2001, 2003), which are within the limits of those established in the host andesites and basement rocks, and as a whole are higher than the ratios typical of Upper Cretaceous fluids of marine origin. This practically does not permit to evaluate unequivocally the participation of meteoric water in the system, which precipitated the principal economic ore mineralization in the deposit.

The specific features of the mineral-forming processes are reflected by the presence of several morphogenetic types of structures, established in the ore bodies. The massive ore type is the most common and to a large extent imparts the pattern of the economic mineralization forming pipe-like, lens-shaped or irregular ore bodies. Furthermore there are also vein-like and "stockwork"-type bodies, which are typical of sectors with more intense development of hydrothermal alterations. Banded type structures are of limited occurrence and are related to zones of framboidal pyrite – the result of hydrothermal-sedimentary ore deposition mainly in the higher levels of the deposit. The vein type is more characteristic of the peripheral parts of the ore bodies, but practically is found throughout the whole section of the deposit. The predominance of galena and chalcopyrite in this type is typical of the transition to lower-temperature and lower sulphidation state conditions of mineral deposition.

As a whole the spatial development of ore deposits in Elatsite–Chelopech ore-magmatic system distinctly reveals a specific lateral and vertical zoning. It is expressed by localization of massive sulphide ore bodies in the higher central parts of the stratovolano. At the same time the porphyry ore deposits concentrate around the small subvolcanic-hypabyssal intrusives emplaced in lateral magma channels aside of the principal volcanic channel. The vein ore deposits are localized at a larger distance, in the peripheral parts of the volcano-plutonic complex. It has been also established that the magmatic and ore-forming processes migrate in time from the northern towards the southern parts of the ore field at the time of formation of the intrusive-volcanic complex.

2.3. Field stop 3. The recreation complex of Chelopech mine: Early copper and gold metallurgy

(Kalin Dimitrov)

Which are the first metals discovered by men? When and where did happen this discovery? How did the use of metals influence the society development?

This interest to the history of metals is more than natural having in mind their impact on the human civilization evolution.

The first metal used by mankind was copper. This is due to an evident reason: the native copper is relatively common to be found in nature and is easily accessible on the ground surface since ancient times. The earliest metal objects in the world are discovered during archaeological excavations of Early Neolithic settlements (Ashikli Huyuk, Çayönü tepe, etc.) in the Asian part of the present territory of Turkey. They are dated as belonging to the IX–VIIIth millennia BC. The finds include small copper objects: beads, awls, plates and other decorations. They are manufactured by hammering of native copper pieces, rasping and cutting of plates. This ancient technique of metalworking uses only one of the metal properties – its malleability and does not provide with the possibility of manufacturing larger object with more complex shape. The Early Neolithic Anatolian copper metalworking technique uses very little the heat. The metallographic investigations of some of the awls found in Çayönü tepe show that they were probably somewhat heated several times during the manufacturing in order to avoid the hardening effect after hammering and to restore its malleability properties. In spite of the application of this early type of pyrotechnical operation we could not call this Early Neolithic copper objects metallurgy products. They are not the result of ore transformation nor are they manufactured by melting a native metal. Single finds of objects with such manufacture technique are found in later complexes in Anatolia. However, before the Vth millennium BC, such finds are very rare and relate to incident attempts that have not lead to the dominating role of metals in the production and social relations.

The retrospection of the spatial, chronological and quantitative distribution of the early metal objects lead to the fact that only on the territory of present Hungary, Romania, Serbia and Bulgaria there is an accumulation of copper objects in the Vth millennium BC. Today several thousand copper objects are recorded – massive tools and weapons (chisels, axes, adzes, blades of spears, awls, etc.) weighting more than 4.7 tons. The same territory also accumulates thousands of gold objects weighting more than 6 kg and dated in the same Vth millennium BC. After making the same observation about the copper tool wealth of Eastern Europe, at the end of XIXth century (with even less data available) some Hungarian researchers proposed that a new archaeological age division should be introduced between the Neolithic and the Bronze Age, which is characterised by the common use of native copper, and they call it the Chalcolithic (Eneolithic, or Copper) Age.

Thanks to archaeological and archeometric investigations many more data of this historical age are available today and a more reliable and effective description of this period is now possible.

First of all, there is no doubt that in the Vth millennium BC the Balkans hosted a large-scale metallurgical manufacture and (based on different estimations) between several tens and several hundreds of tons of copper were produced. The investigations of the ancient mines discovered so far (Rudna Glava and Ai Bunar) showed that people excavated the near-surface areas of the deposits using trenches, which followed the ore veins. The favoured ore produced were carbonate and oxide minerals of copper. Having in mind that all of the copper objects in the V millennium BC were manufactured of metal with no impurities at all it can be assumed that native copper was used as well.

Achievement and maintaining temperature needed for the melting of copper (1084 °C) was obviously not a problem for ancient craftsmen. They freely dealt with a variety of technologies and were able to produce complex-shaped objects through closed foundry molds with cores. Accumulated knowledge and experience enabled them to successfully control the processes of gas saturation of copper in heating and cooling and to increase the hardness of the working part of the instruments through hammering.

Among the archaeological finds that best present the metallurgy achievements on the Balkans in the Vth millennium BC the first place is preserved for Varna Necropolis discovered in 1972 near the northern coast of Varna lake. By the end of 1991 (the last season of fieldwork) 7500 m^2 were excavated and studied, which included 310 burial complexes dated at 4400–4200 BC. The burial techniques and ceremonies which become known in the Necropolis are unusually complex and until now some of them remain unclear in spite the efforts of many sophisticated interpreters in the last 30 years. The corpses in Varna Necropolis were positioned lying on their backs or side bent position. In many cases the burial site bears only objects and no bodies were found. There are also cases of re-burial ceremonies. There are three burial sites with no skeletons found but instead clayey masks are positioned as to imitate the human face of a natural sized body. Numerous objects are present on these sites. The total amount of metal objects discovered in the Necropolis is above 170 copper weapons, tools and decorations weighing over 30 kg. Most of these are known also as isolated finds from other sites on the Balkans, but this is the only place with such a rich and variable collection of copper objects found so far.

Fig. 34. Varna chalcolithic Necropolis, tomb 43, Late Chalcolithic, end of the V[th] millennium BC – reconstruction (photo: K. Dimitrov)

In fact Varna Necropolis is more famous with its gold finds located in the burial sites: over 3000 objects weighing around 3 kg altogether. Even in the 1970s this treasure was estimated to be the biggest sensation in the European prehistory. This is the only site in the world, where such an enormous quantity of gold objects is found and dated at the beginning of the millennium BC. And not only the quantity is remarkable. More important is the fact that the gold finds are concentrated in several burial complexes: in the symbolic burial sites where only masks are found and also in few other burial sites with skeletons of apparently rich people. Among these a special place is preserved for Grave 43: burial of about 45-year-old tall man with over 900 gold objects weighing over 1.5 kg. Besides the gold finds this site also contains 7 copper tools, flint blades with unique size, stone axes of Alpine jadeite, and rich decorations of Mediterranean shells. The nature of the finds and their location in the tomb leaves no doubt that this is the funeral of a ruler or other extraordinary person in his time.

Although simple in form, most of the gold objects from the Varna Necropolis were made by experienced goldsmiths, who knew how to produce thin sheets (made into applications that were attached to the cloths), closed objects (beads and bracelets) with a spherical section, and massive cast objects.

The hoard of gold artifacts, which were buried in Varna Necropolis, shows that in the V[th] millennium BC there was a well functioning system of extraction and production of gold that served mostly the local elite and provided them with prestigious objects and symbols of their power.

Before the discovery of Varna Necropolis, few people would admit that in such an early age outside the Middle East might be a social structure on whose top should stand so prominent and wealthy elite. Traditionally such high social status is attributed to the time of the first civilizations from Mesopotamia and ancient Egypt that are dated at about 1000 years later than the Varna community.

Shortly after the last burials in the necropolis, an ecological crisis affected the eastern and southeastern parts of the Balkan Peninsula (drought and increase in average annual temperatures) that seriously influenced the population. In this environment, the most ancient metalworking knowledge in Europe was not lost but was transferred to the west and the northwest along the Danube River valley and into the Alpine mountains, where the metallurgy developed in the next centuries using copper alloys.

2.4. Field stop 4. The town of Koprivshtitsa – a museum of the Bulgarian national revival

(Veselin Kovachev)

The town of Koprivshtitsa is located along the valley of Topolnitsa river (Fig. 35) at an altitude of 1050 m. The Sredna Gora Mountain in this region is characterized by oval forms, their main watershed range being covered with wonderful beech trees. In close proximity is the highest peak of the Sredna Gora Mountain – Bogdan (1604 m) as well as many beautiful places and historical monuments around it.

You can reach Koprivshtitsa by rail or by car. The railway station of the town, on the line Sofia–Karlovo–Burgas, is located at 10 km from town and there are regular bus connections servicing each train.

Fig. 35. General view of the valley of Topolnitsa river and the town of Koprivshtitsa (photo: V. Kovachev)

The road connection Sofia–Burgas is the autoroute E871, from which the road to Koprivshtitsa (16 km) is branching. The distance Sofia–Koprivshtitsa is about 110 km.

Foundation

Old legend tells that, during the years after the fall of Bulgaria under the Ottoman Rule (1393), refugees came to live in the beautiful valley of Topolnitsa – descendents of old animal-tending families with big herds. Professor Irechek mentions that among the first settlers there was a very beautiful Bulgarian girl from the village of Rila. She received a ferman from the sultan, which gave the village big privileges. In the ferman Koprivshtitsa was called "Avrat Allan", meaning "The Field of Women". The legends say that a Turk with gilded horse could not pass though the village, and the villagers could wear weapons freely.

According to Nayden Gerov, the foundations of the present-day settlement was laid by aristocrats from Turnovgrad, the capital of the Second Bulgarian Kingdom, who fled the old capital after the Ottoman soldiers captured it, and together with their herds, villagers, servants and movable property moved to the distant and less accessible Central Sredna Gora.

In the end of XVIth c., chased by the Ottoman conquerors, a group of intelligent Bulgarians left their home villages Etropole, Samokov, Turnovo and others, and settled in the middle of the Sredna Gora Mountain, in the foot of the peaks Bogdan and Bunaya, among the picturesque valley of Topolnitsa river – a crossroad of many roads. The place was appropriate for rest of caravans, travellers and tradesmen. Because of the favourable natural conditions, one family came to the region with its heards called "zhupa". They started the new settlement. With the increasing number of people and houses, small communities formed. Nearly every relative recieved a nickname – Tihanek, Kozlek, Duplek, Lomek. From there come the names of the neighbourhoods, some of which have been preserved up to today.

Another legend tells that Koprivshtitsa was a "vakuf" (personal property) of the daughter of the Sultan Suleyman the Great – a Turkish princess famous for her beauty.

Etymology of the name and history of the town

The explanations for the origin of the name of the town have many variants, too. It is considered that the name comes from "Kup rechici" (a bunch of rivers), entering into Topolnitsa; or from the Greek word "kopros" which means dunghill or from dill ("kopar") or nettle ("kopriva").

Because of the privileges, which the people from Koprivshtitsa had, they kept their well-being even after the fall of Bulgaria under the Ottoman Rule. The riches of the town attracted the Kurdzhalii, who three times plundered and chased away its citizens. Koprivshtitsa was burnt down in 1793, 1804 and 1809, but because of patriotism, resourcefulness and assiduousness of its citizens, the city has been renovated and its magical charm is preserved until present days. The village gradually increased as a result of labour, wisdom, and high moralities of its citizens. The number of citizens reached 12,000 in XIXth century – 1600 families, three doctors, 2000 horses and 120,000 sheep.

Tradesmen and craftsmen improved the town – building bridges, water fountains, churches, "Chitalishte" (a cultural and educational centre) called first "Neofit Rilski", then "Hadji Nencho Palaveev" – a rich person from Koprivshtitsa who sponsored culture. Expensive icons were ordered, Bibles in Bulgarian, and students studied in Bulgarian. That is how the generation of Renaissance appeared with humane ideas for spiritual and political freedom from the empire. Its representatives are Todor Kableshkov, Ljuben Karavelov, Georgi Benkovski, Nayden Gerov, Joakim Gruev, etc.

As enigmatic as it is, the oldest history of Koprivshtitsa has a very important place in the Bulgarian Revival. The second peer school in Bulgaria (1837) and the first class school in Bulgaria (1846) opened there. There, on the 20th of April 1876 was fired the first bullet against the Ottoman conqueror and the beginning of the April Uprising started, which is the reason the Third Bulgarian Kingdom to come into being.

Population and handicrafts

The population of Koprivshtitsa has tended animals, design and preparing fur clothes, painting and other crafts. The citizens of the town have proved themselves good tradesmen. Their goods have reached Venice, Istanbul and Alexandria. Proof of that are murals and landscapes from different world cities in Ljutovata, Oslekovata and other Renaissance houses. In the first tens of years of the XIXth century the town has enjoyed proliferation, and improvement as a centre of trade and different traditional handicrafts such as fur dressing, tailoring and others.

Architecture

Koprivshtitsa is a miniature treasury with its notable monuments of architecture and building from the epoch of the Bulgarian National Revival (XVIII–XIXth c.) In the town, which has preserved its original appearance, many old picturesque houses are situated and together with the water fountains, arched bridges, interesting chimneys, coble streets, brick walls and churches form very interesting ensembles. The architectural-building monuments from the National Revival period here are 388. 15 of them are of national significance.

The most popular among them are:

- The house of Kableshkovi – rich tradesmen and home house of the rebel from the Aprilovski Rebellion – Todor Kableshkov (Fig. 36, left)

- Oslekovata house, which was owned by rich tradesmen in the middle of the XIXth century (Fig. 36, right)
- The home of Georgi Benkovski – rebel from the Aprilovski Rebellion
- The home of the poet, writer and publisher Ljuben Karavelov and his relatives, tradesmen
- Home of the lyrical poet Dimcho Debelyanov.

Fig. 36. Kableshkovata house – museum (left) and Oslekovata house – museum (right) (Photos: V. Kovachev)

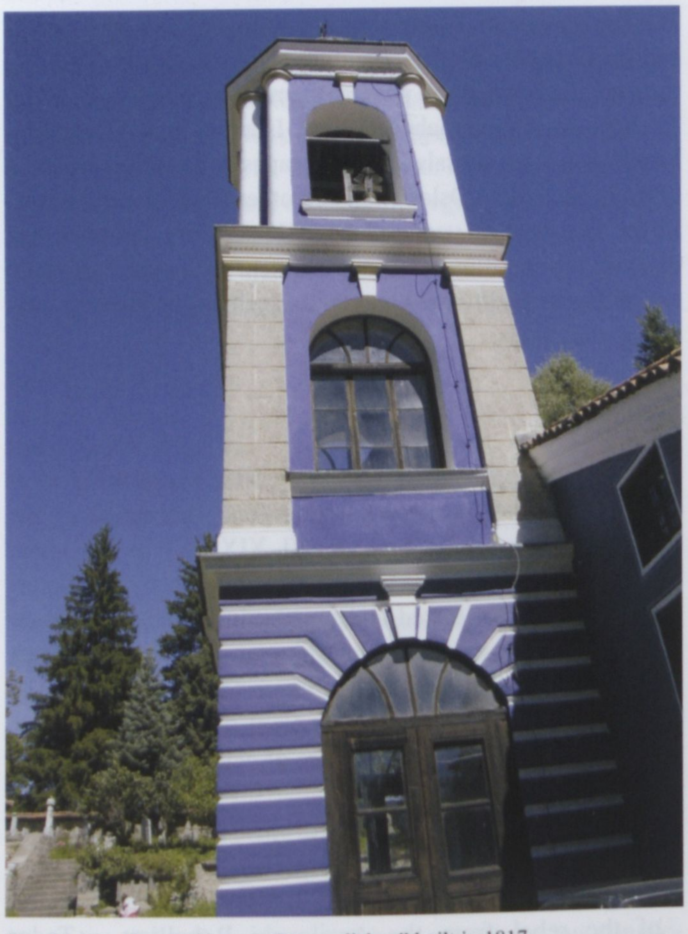

Fig. 37. The church "Uspenie Bogorodichno" built in 1817. (photo: V. Kovachev)

Apart from these National Revival period houses, there are other sights in Koprivshtitsa – the churches "Uspenie Bogorodichno" (Fig. 37) and "St. Nicholas" (built in 1817 and 1845); the school "St. Cyril and Methodius" (Fig. 38, left), built in 1837; the "Town Chitalishte" (town culture centre), built in the beginning of the XXth century (Fig. 38, right). The mausoleum-ossuary built in honour of the people who died in the Rebellion as well as the modern monuments of Todor Kableshkov and Benkovski.

In 1952 Koprivshtitsa has been proclaimed a town-museum, from 1971 – architectural and historical reserve and in 1978 – a national architectural reserve with international significance and centre of international tourism.

Koprivshtitsa has preserved all the features of the overall development of the XVIII and XIX century architecture in Bulgaria. The oldest houses with an architectural value are few. They have been restored but only some elements have been preserved. Such are the Vakarelskata and Pavlikyanskata houses as well as other houses from newer time that have kept elements of the old tradition. Buildings are low, one-storey, floor on the ground. Coniferous trees have been used as building material. Such houses had been built up to 1809 when the town was burnt down and a large part of these buildings was destroyed.

After the fire, a new stage in the development of the town started, during which mainly wooden houses were build – in the beginning one-storey, then two, with more rooms and open (balcony-like) "chardaks". The chardak is open and is positioned along the front of the whole main facade. A major type

Fig. 38. Primary school "St. Cyril and Methodius" (1837) – left; Culture centre – right (photos: V. Kovachev)

was the asymmetrical house, related to the progress of animal tending, craftsmanship and beginning of trade. The development during this period, which finished with the appearance of the symmetrical wooden house with open arch, was influenced by the well-being of people. The main building material was again the wood. The main carrying construction and the panels outside were made of wood, and on the inside the walls were rubbed with clay. Stone was used for the foundations and shaping of gardens.

Little by little the stone took more and more space as a building material. It was used for making masonry on the first floor, whereas the second was made of wooden construction and clay. The stone walls were thick, made of unprocessed stone and the material that kept them together was sand and clay. Levelling of the masonry was done by wooden poles, at different places along the vertical. This approach was used in the two-storey asymmetrical houses. With the passing of time houses became more intricate, with more elements in their construction, and the interior was improved as well.

A completely new architectural style was offered with the rise of the symmetrical house. The main entrance hall "kyoshka" was surrounded by living areas, symmetrically arranged with respect to the entrance. These were houses with bigger living area, two houses and cellar, built primarily for rich people. With the increase of citizens, the free areas for building decreased constantly, which influences the change from square to rectangular format in building and forms of houses became more complicated with spaces of oval forms and arches.

The life in the town of Koprivshtitsa during the Renaissance period was rich in rituals and rites, festivals and religious festivities. Especially flamboyant were the weddings, which took place mostly in autumn and winter months. In general terms, the wedding rituals have been preserved to this day and present a great deal of interest to young people (www.eng.cherga.net).

The natural material used for building was obtained from the vicinity of the town. The wood material was beech or coniferous from the nearby forests. Oak wood was used only for the most open parts of the carrying construction of the houses. The reason for this is the lack of this forest species in the surroundings of the town, because of the high altitude. As building stone was used granite from the Koprivshtitsa intrusive, on which the town is situated. According to Nedyalkov *et al.* (2009, unpublished data) the granite from Koprivshtitsa intrusive is leucocratic, two-mica peraluminium granite with Fe-rich biotite, abundant acid plagioclase and weekly expressed schistosity. The age is 312 ± 5.4 Ma (Carrigan *et al.*, 2005) or 304.8 ± 0.8 Ma (Peytcheva *et al.*, 2004). The granite outcrops in a large area in western direction up to the porphyry copper deposits of Medet and Asarel. The best outcrops of these rocks can be found south of the town, and it could be supposed that the building stones were obtained from the area of Smilovyane.

Water fountains

Unchangeable element of the overall architecture of the town is the public water fountains. The slopes of the Valley of Topolnitsa River are rich in springs, which, with the development of the town, were captured and fountains were built. As a result, there are over 40 water fountains built during different periods. Not all of them are preserved today; the most famous ones are – Kerakova (1751), Mirchova (1857), Morovenova (1843) and Beneva (1850). These fountains show the style of building – they have been in-built in the walls of houses and fences, or independently in churchyards, squares and crossroads.

The basic elements of the water fountain are profiled arch and in-built rectangular shallow niche, in the lower part of which is the bed (Fig. 39). In some cases the niche is included in the rectangular profile frame. The result (the indentation where the pot for drinking water is kept) is a significant part of the decoration. It is situated a little lower than the geometrical centre and ends with cobilic form.

The water fountains in Koprivshtitsa are decorated with smaller decorative elements: signs, rosets and lines, stars, images of water, flowers (Fig. 40). The water source, where

Fig. 39. Construction of the Chalakova fountain in an avant-corps wall (photo: V. Kovachev)

crystal clear water gushes out, is at the base of the fountain.

The street water fountains in Koprivshtitsa are built of soft malleable stones that allow engravings.

Such materials are not to be found in the region. Macroscopic studies of building stone established that most probably it was talc schist from the ophiolitic complex. Such rocks are rare in Bulgaria but are widespread in the Vardar Zone (Fig. 4). Ultrabasic rocks including talc schist are known near the village of Zhivkovo, Ihtiman, Sredna Gora Mts. (about 50 km southwest) and south from the town of Kardzhali (about 150 km southeast), where a small quarry operates for exploitation of talc schist.

This suggests that the building material for part of the Koprivshtitsa water fountains has been supplied from one of those regions, regardless of the large distances.

Bridges

Especially interesting with its unique architecture are the numerous arch bridges with expressive and perfection form and line. The beautiful rainbow dominates on arches. Upon the stones are written the year and the donor, which shows the significance of building that society placed upon. The more famous bridges are Klachevia of 1813. This high arch bridge (Fig. 41) has turned into one of the symbols of Koprivshtitsa. It was made of rough granite stones in 1813 with funds from Hadji Nayden Kaluchev (that's where its name comes from). The building materials are identical with those for building houses and originate from the Koprivshtitsa intrusive. The bridge is also famous as The Bridge of the First Gunshot, because on 20 April 1876 the first gunshot of the April Rebellion was went off here. Other famous bridges are the Kerekovya and Peyovskia Bridge.

Fig. 40. Elements of the decoration of the Chalakova water fountain
Sign with engraving on an arch niche, decorated with lines and rosets (left); six-angle star (right) (photo: V. Kovachev)

The bridges of Koprivshtitsa are significant for the overall architecture and face of the town. But it has actual sounds, having in mind the motto of the IMA congress. The bridges are everywhere in the world and connect people, but they are different in form, building style, building material, etc. This emphasises the numerous possibilities for understanding between people, information between the different cultures, exchange, one cleaner planet and a better life.

Fig. 41. Kalacheviat Bridge in Koprivshtitsa – epitome for building arch bridges (photo V. Kovachev)

2.5. Field stop 5. Asarel porphyry copper mine

(Strashimir Strashimirov, Veselin Kovachev, Veselin Mladenov & Danail Yovchev)

Geology of the Asarel–Medet ore field

The Asarel–Medet ore field is situated about 10 km to the NW of the town of Panagyurishte, 70 km E-SE of the city of Sofia and 60 km NW of the city of Plovdiv (Fig. 42). The Asarel–Medet ore field is controlled spatially by ore-bearing magmatic structure with same name. It is exposed in the centre of the Panagyurishte ore region, within the core and the southern limb of the Laramide Srednogorie anticlinorium.

The area of Asarel–Medet ore field is built of Precambrian metamorphites, Paleozoic granitoid (304–305 Ma, Peytcheva *et al.*, 2004) and gabbroic rocks (305 Ma, Peytcheva *et al.*, 2004) in the basement, and Upper Cretaceous magmatites (Fig. 42).

The Upper Cretaceous magmatic rocks are of effusive, neck, subvolcanic and hypabyssal facies. The effusive rocks are represented by lava sheets and tuffs of andesitic to quartz latiandesitic composition. The andesite is mesocratic, massive and distinctly porphyritic rock. The phenocrysts are mainly plagioclase and amphibole, rarely biotite and locally quartz. The groundmass is microlithic, hyalopilitic, pylotaxitic or polyphyric. The pyroclastic rocks have the same composition. Agglomeratic tuffs predominate, block and psammitic tuffs are rare. A volcanic neck, probably of the same composition, is exposed in the area of Rasslatitsa hill (Popov & Petkov, 1994).

The subvolcanic bodies are composed of andesite, rarely dacite or granodiorite to quartzdiorite and diorite porphyrites. The andesite and dacite form predominantly dykes and small dyke-like bodies. The granodiorite and quartzdiorite porphyrites build the Asarel and Lisa Mogila intrusions and several smaller intrusive bodies and dykes.

Hypabyssal rocks of the Medet intrusive (quartz monzodiorite and granodiorite porphyrite) are exposed in the northern part of the ore field.

The following paleovolcanic and magmatic structures are distinguished in the ore field (Popov *et al.*, 1997).

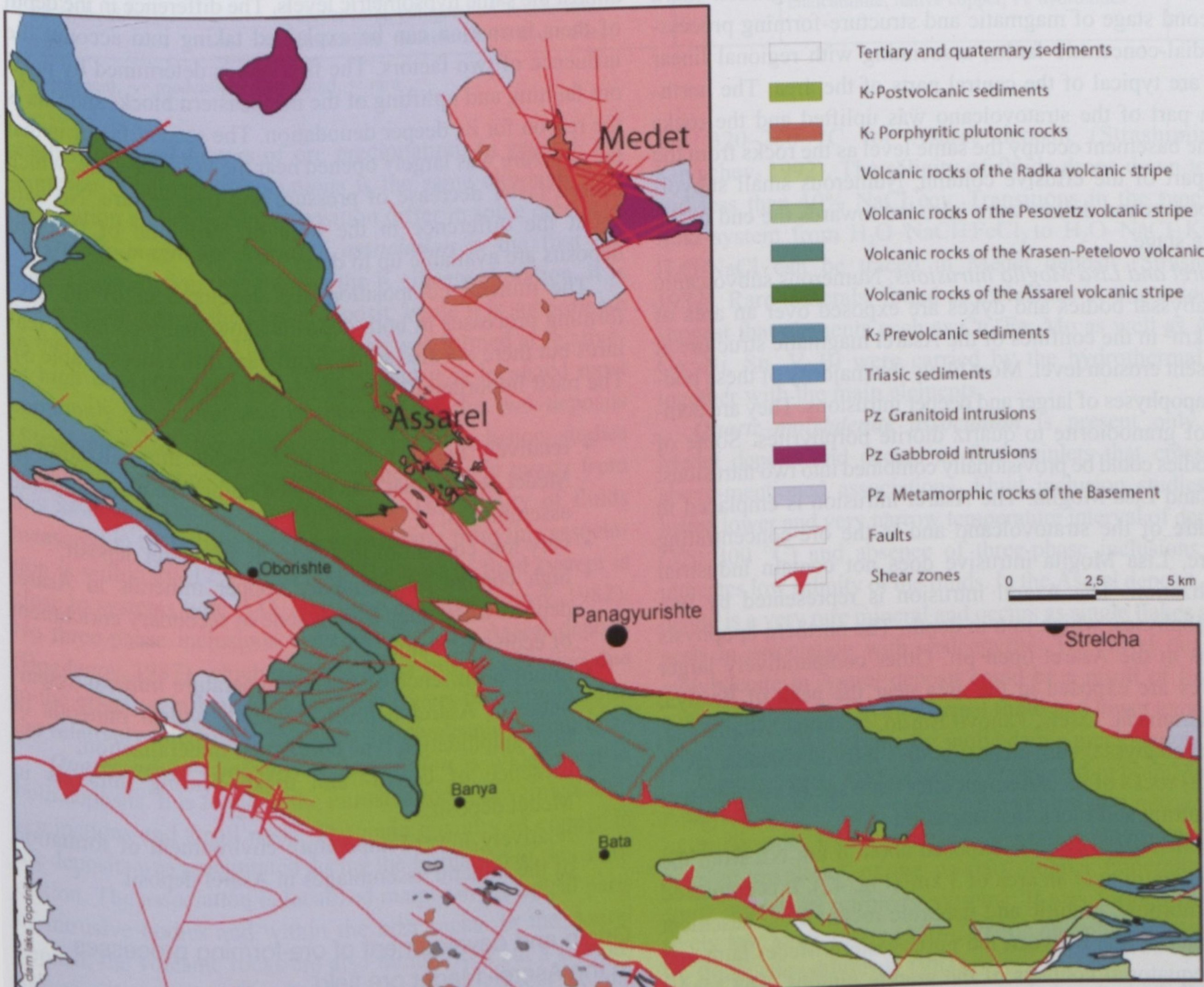

Fig. 42. Schematic geological map of Panagyurishte ore region and location of porphyry copper deposits Asarel and Medet (after Ignatovski & Bayraktarov, 1996; Nedyalkov *et al.*, 2007)

Asarel–Medet volcano-intrusive structure

The Asarel–Medet magmatic structure is very complicated. It is built up by the Asarel volcano, Asarel, Lisa Mogila and Medet intrusions and many other small intrusive bodies and dykes. Intensive volcano-tectonic faulting and block disintegration are characteristic features of the structure. Its spatial position is determined by the area of crossing and joining of faults with W–NW (110–130°) and N–NW (150–160°) direction.

Asarel volcano. The Asarel stratovolcano is situated 2–6 km to the northwest of the town of Panagyurishte (Fig. 42). It marks the first stage of magmatic activity. The central part of the volcano is predominantly build up by lava and brecctiated lava sheets, as well as coarse-grained pyroclastics and block tuffs. In western direction the volcanic column comprises mainly pyroclastic rocks, including fine-grained varieties (Popov & Petkov, 1994). The volcanic centre is marked by a volcanic neck and concentration of small subvolcanic intrusions and dykes. The lava sheets and pyroclastic layers dip radially from the centre to the periphery of the structure at angles of 20–40°.

Volcano-tectonic faulting and block disintegration mark the second stage of magmatic and structure-forming processes. Radial-concentric faults, associating with regional linear faults, are typical of the central parts of the area. The northeastern part of the stratovolcano was uplifted and the rocks from the basement occupy the same level as the rocks from the upper part of the effusive column. Numerous small subvolcanic bodies and dińkes were intruded towards the end of the effusive stage.

Asarel and Lisa Mogila intrusions. Numerous subvolcanic to hypabyssal bodies and dykes are exposed over an area of 15–18 km^2 in the confines of the Asarel magmatic structure at the present erosion level. Most likely the majority of these bodies are apophyses of larger and deeper intrusions. They are composed of granodiorite to quartz diorite porphyrites. Some of these bodies could be provisionally combined into two intrusions: Asarel and Lisa Mogila. The Asarel intrusion is emplaced in the centre of the stratovolcano and is the ore-concentrating structure. Lisa Mogila intrusive does not contain industrial mineralization. The Asarel intrusion is represented by two main apophyses, which join in depth. The northern apophysis outcrops in the Asarel open pit. Other comparatively larger intrusives are exposed in the area near the peak of Bratiya, Sivata Gramada, Lisets, Panovo Burdo, Dounina Mogila, etc. These hypoabyssal-subvolcanic bodies intrude volcanic rocks as well as rocks of the basement after the stage of volcano-tectonic faulting and block disintegration.

The Medet intrusion is exposed about 6 km NE from the volcanic centre over an area of 3 km^2 (Fig. 42). It is emplaced in metamorphic, granitic and gabbroic rocks of the basement at the intersection between the northwestern Medet fault and the subequatorial contacts of the granite plutons. The Medet intrusion consists of two successively intruded magmatic impulses. As a whole, the intrusive has a complex morphology and resembles a short columnar lamella oriented 150–160°. The magmatic channel dips steeply to the southwest (190°).

The subvolcanic and hypabissal intrusions are accompanied and supervened by faulting and fracturing of radial-concentric or linear type. New faulting took place during the Laramide deformations.

The Asarel, Medet, as well as 14 other ore occurrences and several ore shows are localized within the ore field. The two main deposits are of similar ore type but show many specific features, which are determined mainly by the different depth of their formation. The Medet deposit is a copper-molybdenum type and is localized within the Medet intrusion. Rocks around the deposit are comparatively weakly deformed and their permeability is low. The chalcopyrite-molybdenite mineralization associates with K silicate alteration. The Asarel porphyry copper deposit was formed under subvolcanic conditions around the neck of the volcano. The host rocks are intensively tectonically disintegrated and their primary and secondary permeability is very high.

The Asarel and Medet deposits are localized at present at almost the same hypsometric levels. The difference in the depth of their formation can be explained taking into account the influence of two factors. The first one is determined by post-ore faulting and uplifting of the northeastern block, and this is the reason for its deeper denudation. The second factor is that the structure was largely opened near the volcanic neck, which caused faster decrease of pressure and temperature. No data about the difference in the time of formation of the two deposits are available up to date.

The mineral composition and development of the ore-forming processes in both deposits show many common features but there are also some significant differences (Table 5). The most important differences are as follows:

- relatively higher content of Fe oxide mineralization in Medet deposit that was formed before the main sulphide assemblages;
- very low content of molybdenite in Asarel deposit;
- high content of secondary copper minerals in Asarel deposit where they form a zone of secondary enrichment of economic value;
- minor occurrence of lower temperature mineral assemblage in Asarel deposit including typical minerals of high-sulphidation type epithermal mineralization;
- presence of cobalt- and nickel-bearing minerals in Medet deposit;
- relatively lower-temperature environment of formation of the mineral assemblages in Asarel deposit.

Origin and development of ore-forming processes in the Asarel–Medet ore field

As mentioned above, both mineralizations are products of typical development of porphyry copper systems. The differences

Table 5. Mineral composition and sequence of ore-forming processes in Asarel and Medet deposits

Deposit	Asarel		Medet	
Ore mineral associations	Minerals	T (°C) distribution	Minerals	T (°C) distribution
quartz–magnetite–hematite	magnetite, hematite, maghemite, Ti-rich magnetite, rutile, quartz	no data +	magnetite, hematite, maghemite, Ti-rich magnetite, rutile, Mn-rich ilmenite, ilmenite, davidite, pseudobrookite, quartz	400–370 +
quartz–pyrite–chalcopyrite (±molybdenite)	pyrite, bornite, chalcopyrite, pyrrhotite, arsenopyrite, galena, sphalerite, tennantite–tetrahedrite, marcasite, sulvanite, colusite, arsenosulvanite, hessite, mackinawite, enargite, goldfieldite, aikinite, wittichenite, molybdenite, electrum, quartz, chlorite	320–280 +++	pyrite, chalcopyrite, bornite, pyrrhotite, carrolite, Co-rich pyrite, galena, sphalerite, marcasite, sulvanite, colusite, hessite, electrum, molybdenite, quartz, chlorite, biotite	380–320 +++
quartz–molybdenite	–	–	quartz, molybdenite, pyrite	320-300 ++
quartz–pyrite	quartz, pyrite, chalcopyrite, native gold	280-240 ++	quartz, chalcopyrite, pyrite,	280-240 ++
quartz–galena–sphalerite	quartz, galena, pyrite sphalerite, chalcopyrite	240-200 +	quartz, galena, pyrite sphalerite, chalcopyrite	240-220 +
calcite–zeolite	calcite, gypsum, anhydrite stilbite	200 ++	calcite, stibnite, stilbite, heulandite	200 ++
chalcocite–covellite	chalcocite, covellite, anilite, bornite	+++	chalcocite, covellite, bornite	+
malachite–azurite + Fe–hydroxides	malachite, azurite, native copper, antlerite, chrysocolla, palygorskite, brochantite, chalcantite, melanterite, Fe hydroxides	++	malachite, azurite, djurleite, cuprite, tenorite, chalcanthite, native copper, Fe hydroxides	+

+++: frequent, ++ moderately distributed, +: rare

result from local factors of ore precipitation. In general, the sequence of mineral associations is the same although their distribution and mineral composition differ in some details.

Quartz–magnetite–hematite association is the first ore mineral association that follows the K silicate alteration. It is better developed in the Medet deposit, while it is subordinate in the Asarel deposit. The association was formed at relatively high temperatures (400–370 C°) and it is localized most commonly in central and deeper part of the two deposits (Strashimirov & Kovachev, 1992). Fluid inclusion studies found rare presence of three-phase inclusions in quartz from this association in the Medet deposit. The salinity of fluids measured in two-phase inclusions in quartz from this association is within 20–12% NaCl equ. The type of fluid system is close to systems type H_2O–NaCl±$FeCl_2$ (Strashimirov, 1982). No three-phase inclusions were found in the Asarel deposit (Bogdanov, 1987), which suggests lower salinity of brines due to the effective influence of meteoric waters that circulated in the relatively intensively fractured paleovolcanic structure.

Quartz–pyrite–chalcopyrite association is widespread in both deposits. It is found in the intrusive rocks as veinlets, disseminations and small nests. The main quantity of copper in the deposits was precipitated during the formation of this association. The association is localized mainly in the apical parts of intrusive bodies and within the host rocks. In the Asarel deposit, the volcanic rocks are also mineralised but a secondary covellite–chalcocite mineralization was formed by the alteration of primary chalcopyrite. The temperature interval of deposition of this association is 380–320 °C for Medet deposit and 320–280 °C for Asarel deposit (Strashimirov & Kovachev, 1992). The salinity of fluids drops down to about and less than 10% NaCl eqv. Transitions in the type of the fluid system from H_2O–NaCl±$FeCl_2$ to H_2O–NaCl–KCl and H_2O-NaCl can be traced in Medet deposit (Strashimirov, 1982). Rare minerals, found as inclusions in this association, suggest that elements such as Cu, Fe, Mo as well as Au, Ag, Co, Ni, Sn, V, Bi were carried by the hydrothermal brines together with the main elements.

Quartz–molybdenite association is present only in the Medet deposit and occurs as fine veinlets that crosscut the above-mentioned associations. Fluid inclusion studies established lower and very narrow temperature interval of deposition (320–300 °C) and absence of three-phase inclusions, which indicates low salinity of the fluids. In the Asarel deposit, molybdenite is a very rare mineral and occurs as single flakes and fine nests in association with chalcopyrite. The lower quantity of molybdenite in Asarel deposit could be a result of lower Mo content in the initial hydrothermal fluids and lower temperature, which are not favourable for molybdenite precipitation.

Quartz–pyrite association is developed in both Medet and Asarel as well-shaped veins in the central and marginal parts of the deposits. Its appearance is an expression of the so-called "pyritic envelope" of the primary copper mineralization in some models of porphyry systems. It was formed from relatively low temperature (310–280 °C) and probably low salinity fluids (Strashimirov, 1982).

Quartz–galena–sphalerite association is typical for the upper and marginal parts of porphyry deposits. In both deposits it is represented by fine veins of white quartz with nests of sphalerite, galena and minor chalcopyrite and pyrite. The temperature of formation is about 280–240 °C. No data are available for salinity of parent fluids but it is supposed to be very low.

Calcite–zeolite association marks the final event of hydrothermal activity in both deposits. It is observed as fine nests of different size and oriented veinlets, mainly of calcite and rarely zeolites (stilbite, laumontite, heulandite) that crosscut the host rocks.

Supergene alteration processes are intensive in the Asarel deposit and of limited occurrence at Medet, where they affect the uppermost levels of the deposit. Secondary copper minerals in Asarel form a zone with about 70–90 m thickness, which determines the economic value of this deposit.

The supergene alteration processes generated two associations.

Chalcocite–covellite association forms nests, veinlets and disseminations in the hydrothermally altered volcanic rocks in the Asarel deposit, whereas in Medet it is found in single veinlets, tarnish and small nests in the uppermost levels of the Medet deposit.

Malachite–azurite association is poorly developed in both deposits.

The Asarel porphyry copper deposit

The Asarel–Medet JSC Open pit (Fig. 43) and Processing Complex is the first, largest and leading Bulgarian company for mining and processing of copper and other types of ores providing more than 50% of the national production of the vital metal for human development – copper. Asarel–Medet JSC produces copper concentrates, cementation and cathode copper of high quality. It traditionally exploits the largest quantity of material in the Bulgarian ore mining industry and processes about 13 million tons of ore per year, thus ensuring sustainable development and thorough utilization of the mineral raw materials of Asarel deposit.

Geology

The deposit is located in the central part of the Asarel volcano in an area of intensive radial and concentric faulting and fracturing (Fig. 44). The central part of the volcano consists predominantly of lavas and brecciated lava sheets, and pyroclastics of dominantly andesite and latite-andesite composition.

The Asarel granodiorite porphyrite is located in the centre of the former stratovolcano and consists of two apophyses that join at depth. The northern apophysis outcrops in the open pit, which is located at the side of the former hill shown on Fig. 43. The ore mineralization forms a cone whose top is inclined at 80–85° towards the south and southwest. The horizontal cross-section of the deposit, therefore, has an ellipsoidal shape with a long axis oriented in N–S direction. All host rocks are very intensely altered. The eastern part of the structure is uplifted and altered basement metamorphic rocks are now exposed at the same structural level as the volcanic rocks affected by advanced argillic alteration. It is characterized by the following hydrothermal alteration: K silicate, propylitic and advanced argillic – acid-chlorine and acid sulphate subtype (Kanazirski 1994, 2000a, 2000b). Sericitic alteration in these deposits is developed separately or in mixed propylitic–sericitic and sericitic–advanced argillic ones.

Hydrothermal alteration

Mineralogical observations in the upper levels of Asarel deposit revealed the following pre-ore hydrothermal alteration within the subvolcanic–hypabyssal bodies, volcanic rocks and Paleozoic granitites: propylitic, propylitic–argillic, propylitic–sericitic, sericitic, sericitic–advanced argillic and advanced argillic–acid chloride and acid sulphate subtypes (Fig. 45, Kanazirski 1994, 2000a, 2000b). The distinctive mineral parageneses for the different types are shown in Table 6. A typical cross-section in the central part of the deposit is shown on Fig. 45, which also illustrates the spatial distribution of the most commonly found alterations.

K-feldspar–biotite alteration as relict in some areas of propylitized granodiorite porphyrites and Paleozoic granitites, are reported by Arnaudova *et al.* (1991) K silicate and K silicate–propylitic alteration are sporadically found in the upper levels of Asarel deposit (Kanazirski *et al.*, 2000). Epithermal sericitization and advanced argillization in the lithocap are observed to overprint propylitic and K silicate alteration.

The propylitic alteration is best developed within the Upper Cretaceous volcanic rocks, in the subvolcanic-hypabyssal bodies and partly within the Paleozoic granites. Propylitic–argillic

Fig. 43. General panorama of Asarel open pit (photo: K. Dimitrov)

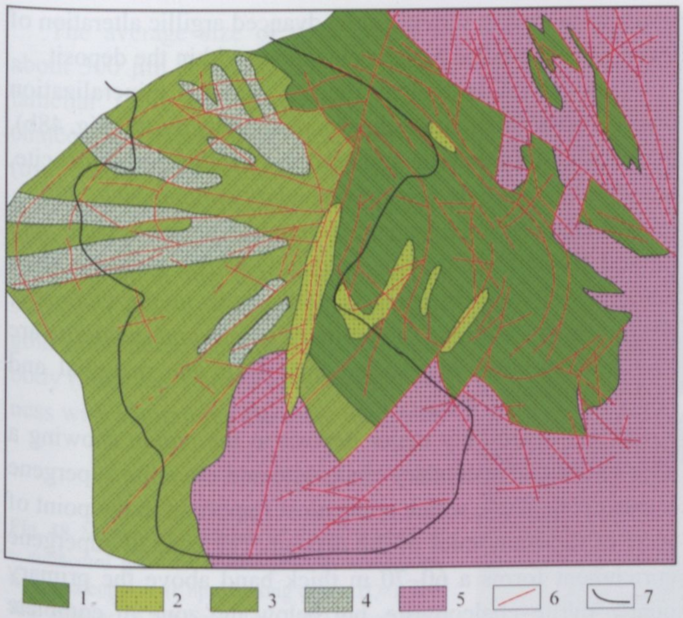

Fig. 44. Lithologic-structural scheme of Asarel deposit (after Popov *et al.*, 2000)
1 – Granodiorite porphyrites altered in propylitic–argillic facies; 2 – Granodiorite porphyrites altered in advanced argillic facies; 3 – Andesites altered in propylitic–argillic facies; 4 – Andesites altered in advanced argillic facies; 5 – Paleozoic granites, propylitized; 6 – Faults; 7 – Contour of the ore body

and propylitic–sericitic alterations are found in the transitional zone toward the propylitic alteration (Kanazirski, 2000a, 2002). Mineral assemblages including illite + quartz + pyrite + pyrophyllite (kaolinite) define transitional sericitic–advanced argillic type (Fig. 46) of alteration (Kanazirski *et al.*, 1995, 2000).

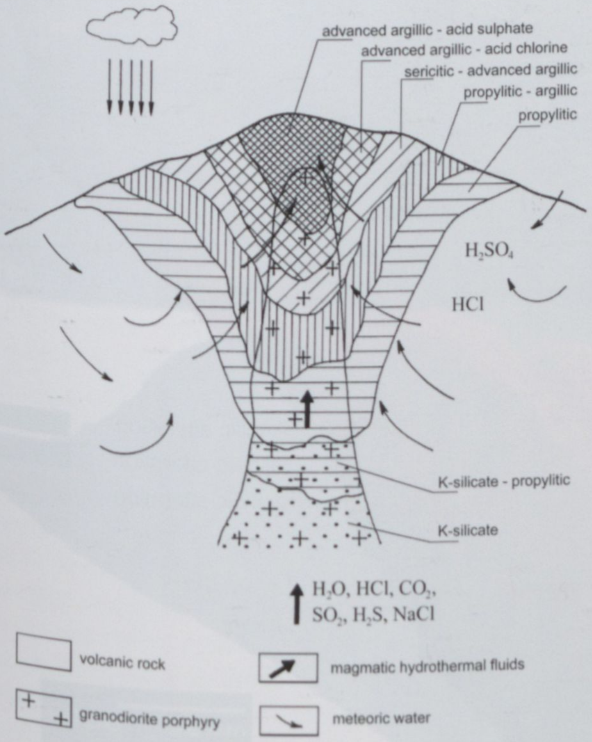

Fig. 45. Schematic sketch showing distribution of different alteration zones in Asarel deposit (after Kanazirski *et al.*, 2000)

Table 6. Mineral assemblages and wallrock alteration in the shallow parts of Asarel deposit (after Kanazirski *et al.*, 2000; Strashimirov *et al.*, 2002).

Wallrock alterations	Mineral paragenesis
Propylitic	ep + chl + ab + ksp + il + qtz + py chl + ab + ksp + il + qtz + py chl + ab + il + qtz + py
Propylitic argillic	chl + kl + ab + il + qtz + py ± ep ± ksp kl + ab + il + qtz + py
Propylitic–sericitic	chl + il + qtz + py
Sericitic	il + qtz + py
Sericitic–advanced argillic	il + qtz + py + prl il + qtz + py + kl
Advanced argillization (acid chloride subtype)	prl + qtz + py kl + qtz + py
Advanced argillization (acid sulphate subtype)	alu + qtz ± prl ±py ± hem alu + qtz ± kl ± py ± hem

ab – albite, **alu** – alunite, **chl** –chlorite, **ep** – epidote, **ksp** – K-feldspar, **kl** – kaolinite, **hem** – hematite, **il** – illite, **prl** – pyrophyllite, **py** – pyrite, **qtz** – quartz.

Advanced argillic alteration is present in the two subtypes of acid-chlorine and acid sulphate alteration. The porphyritic textures are overprinted and obscured in the acid-chlorine subtype and the rocks are composed of pyrophyllite, quartz and pyrite ± diaspore, corundum, zunyite and kaolinite. The paragenesis kaolinite + quartz + pyrite is rare (Table 6). The sequence of acid chloride and acid sulphate sub-types in the Asarel deposit, as well as the ratios between alunite and kaolinite to pyrophylite and the precipitation of alunite + kaolinite suggest changes of chlorine-acid fluids to sulphur-acid ones. Similar mineral parageneses typical for advanced argillic alterations are described in high sulphidation type epithermal deposits (Silberman & Berger, 1985; Sillitoe, 1991, 1995; Eaton, 1993; Arribas, 1995 and others).

Formation-facial analysis allows distinguishing between alteration assemblages that are the result of epithermal advanced-

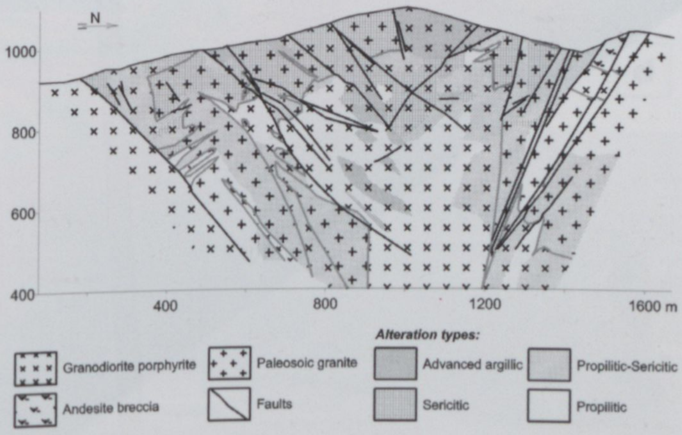

Fig. 46. Section with the typical alteration types of Asarel deposit – central part (after Popov *et al.*, 1996).

argillic acid development. Thus, a kaolinite–pyrophyllite facies in a secondary quartzite formation can be separated from the quartz–alunite facies in the same formation (Table 7, Fig. 46; Kanazirski, 1998; Kanazirski *et al.*, 2000).

Practically, the three principal types of hydrothermal alteration – argillization, silicification and propylitization (Fig. 47) can be mapped during the exploitation of the deposit.

Mineral composition

An early quartz–magnetite–hematite association, which is very typical for the porphyry copper deposits in the region, occurs in a very limited extent in the Asarel deposit, where the late quartz-molybdenite association is also very rare (Bogdanov, 1987). Quartz–pyrite–chalcopyrite association (Table 5) has a wide distribution in the middle and marginal parts of the deposit. Quartz–galena–sphalerite association is rarely developed, mainly in the upper part of the deposit. Galena and sphalerite are occure in well-shaped veins of chalcopyrite at depth as well. Several poly-elemental assemblages characteristic to the high-sulphidation style are established in the upper levels (Petrunov *et al.* 1991).

These assemblages include enargite, goldfieldite (Cu-As±Te assemblage), colusite, As-sulvanite and sulvanite (Cu-Sn-V assemblage), aikinite and wittichenite (Cu-Bi assemblage), hessite (Fig. 48a) and tetradymite (Bi-Ag-Te assemblage) found as fine mineral inclusions in chalcopyrite. It is spatially related to sericitic and advanced argillic alteration of volcanic rocks in the highest elevations within the deposit.

Chalcopyrite is typical for the primary mineralization where it often forms fine veinlets crosscutting pyrite (Fig. 48b). Relicts after chalcopyrite, replaced by covellite and chalcocite, are often found in the zone of secondary enrichment.

Minerals from the tennantite–tetrahedrite series have very limited distribution: they occur mainly as fine grains in chalcopyrite or along its contacts with pyrite in the chalcopyrite–pyrite association. The grains of galena and sphalerite are also found in this association, mainly in the marginal and upper levels (Fig. 48c).

Asarel is the only major deposit in the region showing a high content of secondary chalcocite and covellite supergene blanket (Fig. 48d), which is the most important in the point of view of the economics of the deposit. The zone of supergene enrichment forms a 60–70 m thick band above the primary quartz–pyrite–chalcopyrite, but below the zone of complete oxidation, which usually occupies the first 10–15 m below the present land surface. A linear enrichment of Cu in the stochwork body in NE–SW direction is known.

Gold in Asarel deposit is rare but is of essential economic interest and its mineralogy is typical of porphyry copper deposits. Relatively higher content of this elements is established at the contact between the zone of oxidation and the zone of secondary enrichment (Strashimirov, 1993).

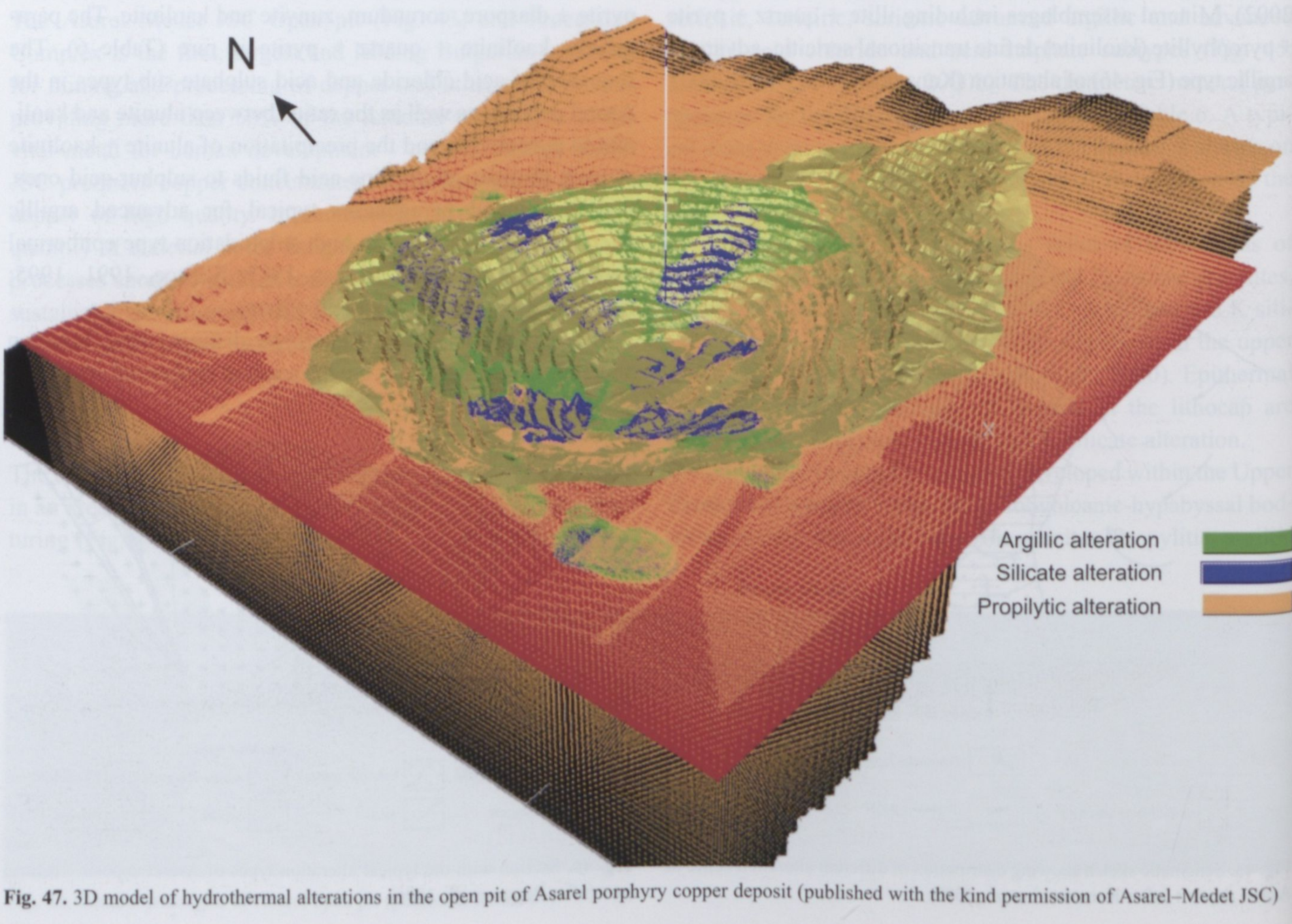

Fig. 47. 3D model of hydrothermal alterations in the open pit of Asarel porphyry copper deposit (published with the kind permission of Asarel–Medet JSC)

The average size of gold grains is about 300 µm (Fig. 49). They occur in lamellar form and accompany mainly chalcopyrite in relatively thicker veinlets (over 1 cm). Gold extracted from the ore is of high fineness (910‰) with admixtures of Ag, Cu and Fe. The high grade of the gold in Asarel is confirmed by studies of gold aggregates from alluvial gold extracted in the proximity to the ore body (less than 1 km). It has 966‰ fineness with admixtures the same elements.

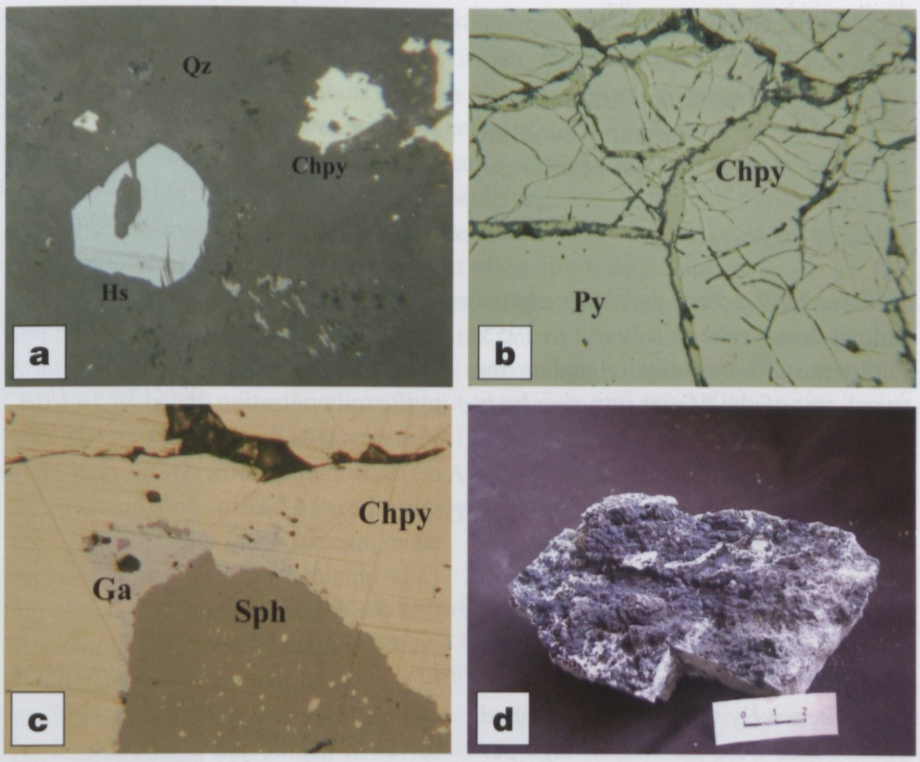

Fig. 48. Mineral associations of Asarel deposit: A – subhedral grain of hessite (Hs) in association with chalcopyrite (Chpy) among quartz (Qz); B – fine veinlets of chalcopyrite (Chpy) crosscutting pyrite (Py); C – galena (Ga) and sphalerite (Sph) in association with chalcopyrite (Chpy) and pyrite (Py). Late galena-sphalerite paragenesis; D – secondary copper minerals (chalcocite and covellite) replacing chalcopyrite (photos: S. Strashimirov)

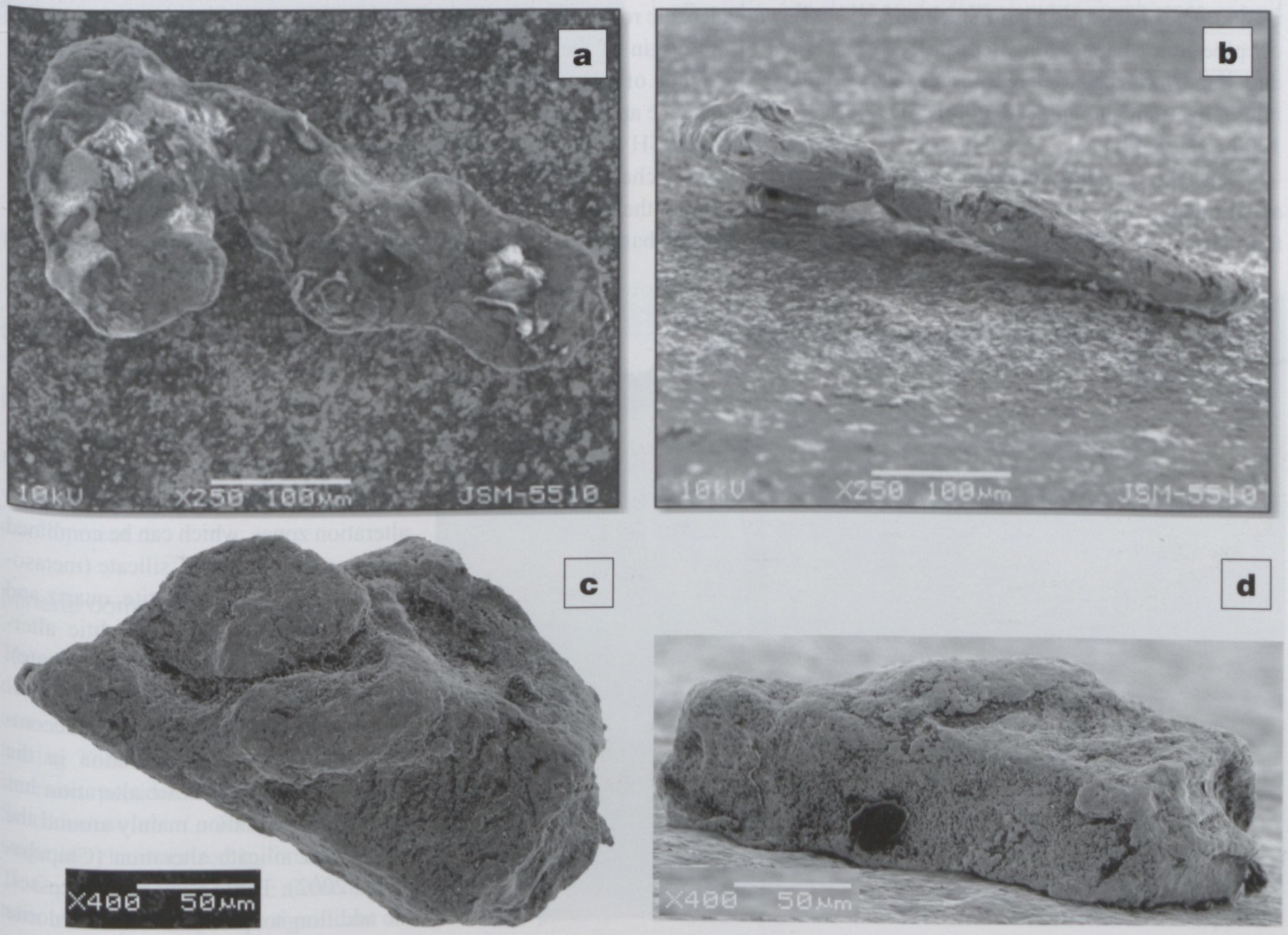

Fig. 49. Gold aggregates from Asarel deposit (SEM). View from two mutually perpendicular directions of gold aggregates from ores in the deposit (a, b) and of alluvial gold from Asarel river (c, d) (photos: V. Kovachev, V. Mladenov, D. Yovchev)

2.6. Field stop 6. Medet porphyry copper mine

(Strashimir Strashimirov, Veselin Kovachev & Veselin Mladenov)

General geology

Medet was the first porphyry copper deposit discovered in Bilgaria in 1955. The deposit is spatially related to the apical part of the Medet intrusive body of quartz monzodiorite and granodiorite porphyrites (Fig. 51) exposed in the N–NE part of the Asarel–Medet ore field (Fig. 42). The basement includes Palaeozoic granite and metamorphites – mainly gneiss. The age of the granodiorite body is Upper Cretaceous. The central and the eastern part of the intrusive body are most intensively fractured and faulted. These zones were the sites of high permeability and host the copper mineralization. The ore body is a large stockwork of pipe-like shape elongated in NW direction. According to borehole data, the mineralization interval extends to over 1000 m in depth.

New data for the duration, sources and timing of the ore-bearing magmatism based on U-Pb dating, Hf-isotope chracteristics and REE patterns have been published by Peytcheva *et al.* (2009). These studies show that the quartz-monzodiorite was intruded at 90.59 ± 0.29 Ma, followed by granodiorite porphyrites at 90.47 ± 0.30 Ma and 90.27 ± 0.60 Ma. Aplite dykes were formed at 90.12 ± 0.36 Ma. Potassic alteration and Cu-Mo mineralization affected these rocks and a later quartz granodiorite porphyrite dyke, containing poor quartz-pyrite mineralization (dated 89.26 ± 0.32 Ma) crosscuts the host rock and the mineralization (Fig. 50). These data show that the ore-bearing magmatism has taken place in a period less than 1.12 Ma. Data obtained by these studies suggest that the Medet magma had mantle and crustal sources. A specific characteristic of the Medet magma is the assimilation of Paleozoic materials, which are themselves of mantle and mantle-crustal origin (Peytcheva *et al.*, 2009).

Lower Paleozoic rocks may have contributed to the origin of the Crateceous magma in the zone of intensive melting, assimilation, storage and homogenization (the so-called MASH zone). Presence of a large magmatic chamber, somewhere about 5 km below the Medet deposit, is presumed on the basis of geophysical data provided by Tzvetkov *et al.* (1978). Later, magma derived from this chamber was further fractioned and additionally contamined by basement rocks (Peytcheva *et al.*, 2009). The development of magmatic and ore-forming processes was influenced by the tectonic regime. The paleostress field was changing during the emplacement of various dyke generations related to the intrusive. The initial stage indicates E–W extension, likely associated with N–S compression, followed by intrusion of the late granodiorite dyke formed in a N–S extensional field. Another very important factor, which controls the formation of poprhyry copper mineralization, is the oxidation stage of the magma. In the model proposed by Peytcheva *et al.* (2009), magma evolution of all main rock varieties (quartz monzodiorite and granodiorite), as well as aplite veins are products of fertile magma. Metals (Cu, Mo, Au) could accumulate in the residual melt phase during differentiation under oxidizing conditions and finally partition into magmatic-hydrothermal fluid phase, when magma reaches fluid saturation, so the late stage fluid phase is characterized by higher concentration of copper and other metals as compared to their reduced counterparts.

Fig. 50. The open pit of Medet porphyry copper deposit. The red arrow points to a late dyke croscutting the rocks and the ore mineralizations (photo: V. Kovachev)

The wallrock alterations in the Medet deposit have been studied by Ushev *et al.* (1962). Interpretation of the published data suggests that the deposit is a representative of the group of deposits where magmatic fluids dominate the hydrothermal system. Ushev *et al.* (1962) established specific mineral alteration zones, which can be combined into two main types: K silicate (metasomatic K-feldspar and biotite, quartz and apatite) alteration and propylitic alteration (chlorite, epidote and carbonate). Epidotization, chloritization and subordinate sericitization commonly accompany the sulphide precipitation in the Medet deposit. Serícititic alteration has a limited distribution mainly around the zone of K silicate alteration (Chipchakova, 2002). These alteration processes, in addition to precipitation of chlorite and biotite, characterize propylitic type of wallrock alteration, which was con-

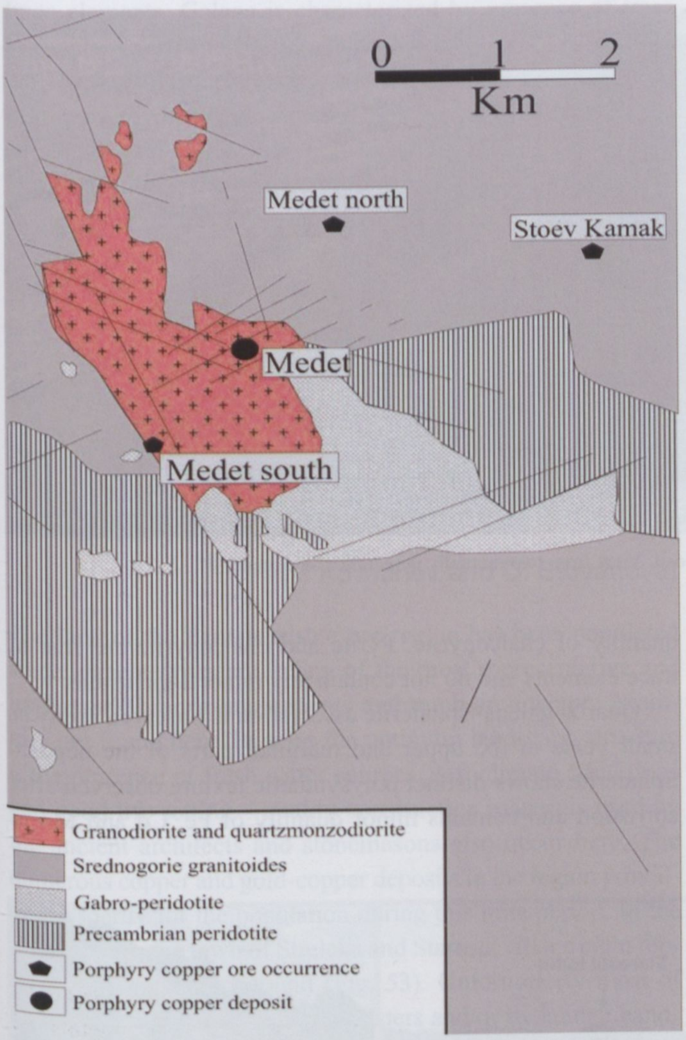

Fig. 51. Map of Medet porphyry copper deposit (after Popov & Popov, 2000)

temporaneous with the precipitation of chalcopyrite and pyrite. The most likely pre-ore metasomatism in the deposit is the pervasive quartz-feldspar alteration.

Wallrock alteration studies by Strashimirov *et al.* (2002) lead to the conclusion that the participation of meteoric waters was limited, especially during the initial stages of the system development.

Mineral composition

The earliest ore mineral association in Medet porphyry copper deposit consists of quartz-magnetite-hematite. This stage was associated with the K silicate ± propylitic alteration, also containing Ti-bearing minerals such as rutile, ilmenite, Mn-rich ilmenite, pseudobrookite and davidite (Strashimirov, 1992; Strashimirov *et al.*, 2002). Hematite and magnetite of this stage are characterized by numerous trace elements (such as Ti, Cr, Mn, Al). These trace elements replace iron in the structure, but they do not cause significant changes in cell parameters, because the presence of some of them (Mn and Ti) increase the size of the elementary cell, but others (Mg and Al) dicrease it and as the combined result of these effects it is close to the standard one. In many cases hematite is altered into magnetite due to changes from oxidative to reductive environment, that favours precipitation of the sulphide mineralization.

The main economic association (pyrite–chalcopyrite) is characterized by considerable precipitation of pyrite and chalcopyrite forming fine grains, small veinlets or replacing some mafic minerals, most often biotite and chlorite.

The main pervasive quartz–pyrite–chalcopyrite association (Table 7) contains mineral inclusions that form specific assemblages. Co-Ni assemblage is represented by carrollite, vaesite, Co- and Ni-bearing pyrite, some of them with a content of cobalt up to 17 wt% (Table 3), Cu-Sn-V (colusite and sulvanite) and Bi-Ag-Te (hessite and tetradymite) assemblages are very rarely found as micrometer-sized inclusions in chalcopyrite.

Table 7. Chemical composition of Ni-rich pyrite (1), Co-rich pyrite (2, 3 and 4) and carrollite (5 and 6) from Medet deposit (Strashimirov, 1982).

Element	1	2	3	4	5	6
Fe	38.20	33.85	30.70	28.90	1.85	2.00
Co	2.20	12.45	15.95	17.85	37.55	38.20
Ni	5.30	0.40	0.05	0.05	3.20	2.25
Cu	0.10	0.10	0.10	0.10	15.90	15.80
S	53.90	53.15	53.90	53.90	41.60	41.90
Total	99.70	99.95	100.70	100.80	100.00	100.15

Crystallochemical formulas:

1. $Fe_{0.81}Co_{0.04}Ni_{0.1}Cu_{0\cdot005}S_{2.00}$
2. $Fe_{0.73}Co_{0.25}Ni_{00.1}Cu_{0\cdot005}S_{2.00}$
3. $Fe_{0.65}Co_{0.32}Ni_{0.005}Cu_{0\cdot005}S_{2.00}$
4. $Fe_{0.63}Co_{0.36}Ni_{0.005}Cu_{0\cdot005}S_{2.00}$
5. $(Cu_{0.77}Co_{0.23})_{1.00}(Co_{1.73}Fe_{0.1}Ni_{0.17})_{1.95}S_{4.00}$
6. $(Cu_{0.76}Co_{0.24})_{1.00}(Co_{1.77}Fe_{0.11}Ni_{0.11})_{1.99}S_{4.00}$

Gold occurs as trace element in pyrite and chalcopyrite, but microscopic observations also found fine micrometer-sized inclusions of native gold in both minerals. The inclusions usually have drop-like shape (Fig. 52) with 30–50 ěm size along the long axis. Quantitative microprobe analyses established that Ag content in these incusions is relatively low (7–8 wt%) in the central parts of the grains and slightly inreases (up to 19–20 wt%) in their marginal parts.

A second generation of magnetite and hematite associates with the main economic mineralization. Here, these minerals are found as fine inclusions usually of euhedral shape and free of trace elements, which are typical for the first generation.

Hessite, tetradimite and vaesite are very rarely observed in the ores, mainly as fine micrometer-sized inclusions in chalcopyrite.

Molybdenite occurs as rare single flakes in this association. It also forms discrete veinlets together with quartz that

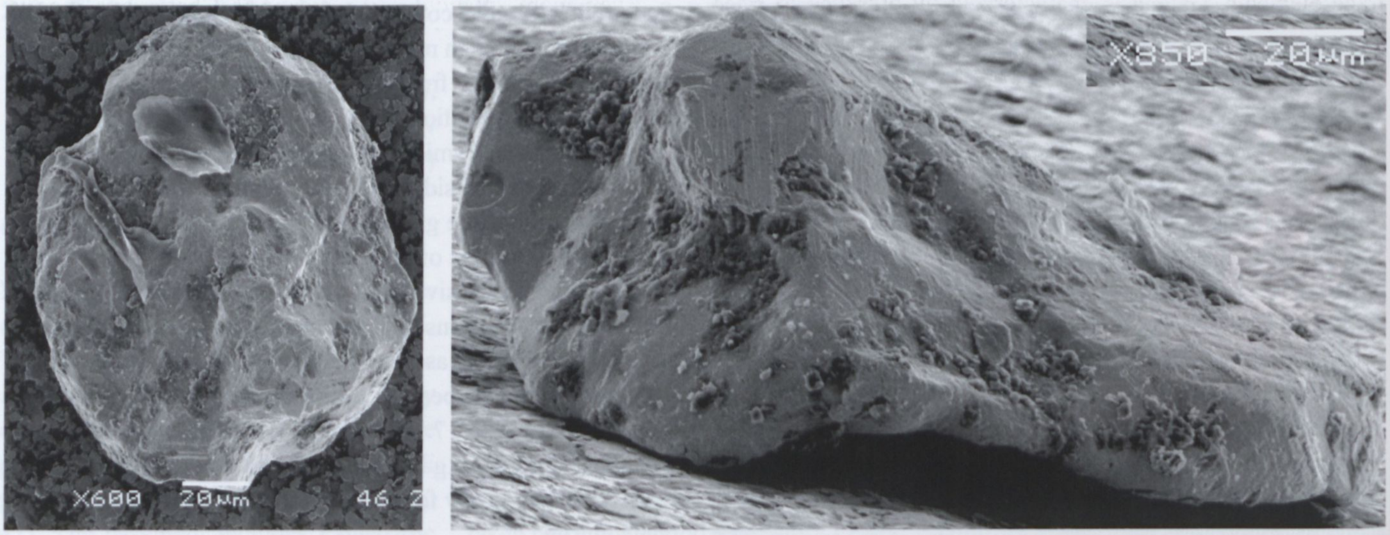

Fig. 52. Morphology of alluvial gold in proximity to the ore body of Medet deposit. View from two mutually perpendicular directions (photo: V. Mladenov and V. Kovachev)

crosscut the products of the main sulphide association. They are denoted as quartz–molybdenite association. 2H and rarely 3R polytypes of molybdenite have been found, the latter one is characterized by the higher content of Re.

Quartz–pyrite association forms well-shaped veins and veinlets in the middle part of the deposit. It contains also minor quantity of chalcopyrite. Pyrite and chalcopyrite are free of trace elements and do not contain any mineral inclusions.

Quartz–galena–sphalerite association is observed rarely as small veins in the upper and marginal parts of the deposit. Sphalerite shows distinct polysynthetic texture observed after corrosion and contains minor quantity of Fe, Cd and Mn as

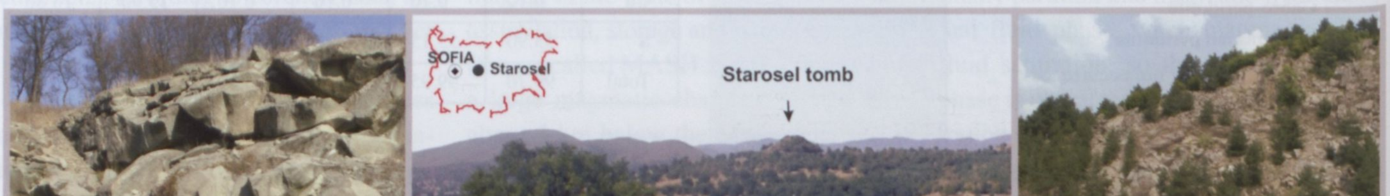

Fig. 53. The Thracian tombs in the area near the towns of Strelcha and Hisarya and sources of the materials used for the construction of Chetinyova mogila tomb

a) View of Chetinyova mogila from east; b) Thracian tombs location scheme of the area between the town of Strelcha and Hisarya; the sources of building material and the probable transportation roads are marked with their approximate length to Chetinyova mogila; ń) Granite quarry in Hisarya; d) Zeolitized tuffs quarry to the NE of Popintsi village (photos and collage: V. Kovachev) trace elements. Galena is characterized by presence of trace elements Ag, Bi and Se (Strashimirov, 1989).

The end of hydrothermal activity is marked by precipitation of anhydrite–gypsum and calcite–zeolite (laumontite, heulandite and stilbite) up to 2–3 cm thick veinlets, replacing and crosscutting the opaque minerals. They commonly occur in the upper peripheral parts of the deposit.

Rare malachite, azurite and cuprite could be observed in the oxidation zone, which is poorly developed. Secondary copper minerals such as bornite, covellite and chalcocite are rarely found in the deposit, mainly in its upper part or along faults in depth.

2.7. Field stop 7. Starosel Thracian tomb Chetinyova mogila

(V. Kovachev and D. Stoyanova)

The land of the Panagyurishte ore region has been populated since ancient times and many of the most representative and important Thracian monuments and tomb architecture examples are found here. Besides the optimum landscape structure – the presence of fresh water sources, soft climate conditions and good life setting – quality construction materials used by the ancient architects and stonemasons also occur here. The numerous copper and gold-copper deposits in the region provided prosperity for the population during this time period. In the area between the town of Strelcha and Starosel village eight representative tombs are found (Fig. 53). Unfortunately most of them are destroyed by natural disasters and/or by human hand.

The most impressive two tombs are Jaba mogila, near the town of Strelcha, and Chetinyova mogila, near Starosel village. Jaba mogila (Fig. 54) is one of the largest tumulus found in Bulgaria and reaches about 20 m in height with diameter about 100 m. The two tombs have distinctive plan scheme, construction type and both are generously decorated with architectural and sculptural elements. The building stones are volcanic tuff, granite and limestone.

Fig. 54. Jaba mogila tomb entrance near the town of Strelcha (photo: K. Dimitrov)

Even more splendid and majestic is Chetinyova mogila tomb near Starosel village. Together with the rest of the tumuli in the region it marks the presence of a large Early Hellenistic period dynasty centre.

Description of the tomb of Chetinyova mogila (Fig. 55)

Chetinyova mogila has long occupied the interest of scientists. Before the summer of 2000 a reliable source of information about this tomb was not present. In 2000 treasure-hunters caused the discovery of remarkable tomb objects and the famous Bulgarian archeologist Georgi Kitov initiated a rescue excavation (Kitov, 2008).

Fig. 55. View of the Chetinyova mogila from south (photo: V. Kovachev)

The Chetinyova mogila is 30 m high and about 80 m in diameter. It is surrounded by a 241-m long impressive crepis wall with height over 5 m, which is built of large well-structured granite blocks (Fig. 56a) joined by iron clamps fixed by lead (Fig. 56b). The blocks were trimmed on the site, which is confirmed by the beds chiseled for obtaining flat surfaces for each block (Fig. 56c). Today preserved height of the crepis reaches up to 3.5 m. The wall contains not less than 5000 trimmed granite blocks, each weighing about 100 kg.

At the southeastern base of the tomb there is a 4-m wide central stone staircase of 9 steps. The staircase is surrounded by a stone wall, which is almost completely destroyed. At the beginning of the staircase there are two bases for pilasters (Fig. 57, left), which formed the monumental propylon. Next follows a platform, which forms the start of the open dromos; and to the east and to the west two lateral staircases climb out of the tumulus. Each dromos is 6 m wide and 10 m long with well-preserved 5-m high walls built of granite blocks (Fig. 57, right).

The facade of the tomb is destroyed but is still impressive by its monumental elaboration. The two pilasters and the jambs of the Ionian doorframe could be distinguished. The door is decorated with painted meander and sculptured Ionian cymation (Fig. 58, top). The presence of architectonic decoration requires the use of softer and easier for carving stone and such

Fig. 56. General view of the crepis (a) and construction details showing the iron clamps fixed by lead joining the blocks (b), which were trimmed on the site as confirmed by the beds chiseled for each following block (c) (photo: K. Dimitrov)

Fig. 57. Left pilaster at the base of the monumental staircase (left) and a wall of granite blocks in the dromos (right) (photo: K. Dimitrov)

are the zeolitized tuffs. The entrance is closed by a two-wing stone door. The wings slide using metal bearings placed onto the door sides in catenary-shaped leads (Fig. 58, bottom). Three steps are climbed before entering the door.

The entrance leads to the antechamber. The larger size of the antechamber required combining a structure of corbel vault with flat roof of plates. In spite the large volume of the tomb mound and the natural hazards during the ages, the soft volcanic tuff appears a reliable solid material that lasted until today. This is a rare preserved example of such construction.

Another Ionian doorframe with generous decoration and ornaments leads to the central burial chamber (Fig. 59). The door wing is built of analcime-bearing tuff and is placed in specific beds chiseled in the floor rock blocks and in the lintel of the entrance (Fig. 60). The burial chamber has a circle-shaped planar section of 5.4-m diameter that proves it to be the largest circle chamber so far found in Thracian tumuli construction. The high walls are decorated by ten Dorian semicolumns that are topped by Dorian entablature consisting of architrave, frieze of metopes and triglyphs and cornice. The built-in columns include individual semidrums and are fluted. On the top is a capital of neck, annules, echinus and abacus. The metopes and the triglyphs still preserve their red and blue paint (Fig. 61). The dome is destroyed but the numerous sector blocks found in the chamber have a complex profile, which allows reconstructing its original shape.

The antechamber walls are constructed using the pseudoisodome technique of alternating sequence of high and low rows of rock blocks, whereas in the burial chamber the technique is much closer to the isodome masonry using similar sized (length and height) stone blocks.

The tomb is documented with great amount of damages and missing objects. Still the preserved architectonic decoration allows relatively high definition estimate of the construction timing. The proportions of the Dorian order (column ratio, capital profile and the frieze architecture) point to the Early Hellenic period at the end of IV$^{\text{th}}$ and the beginning of III$^{\text{rd}}$ c. BC (Stoyanova, 2005).

Mining approach to reaching the inside of the tomb construction

The violent and often vicious penetration in the tomb chambers of many Thracian tombs is commonly observed. In order to avoid further losses a new technology should be established that would allow fast excavation, preservation of the artifacts discovered and estimate of the tomb characteristics. The

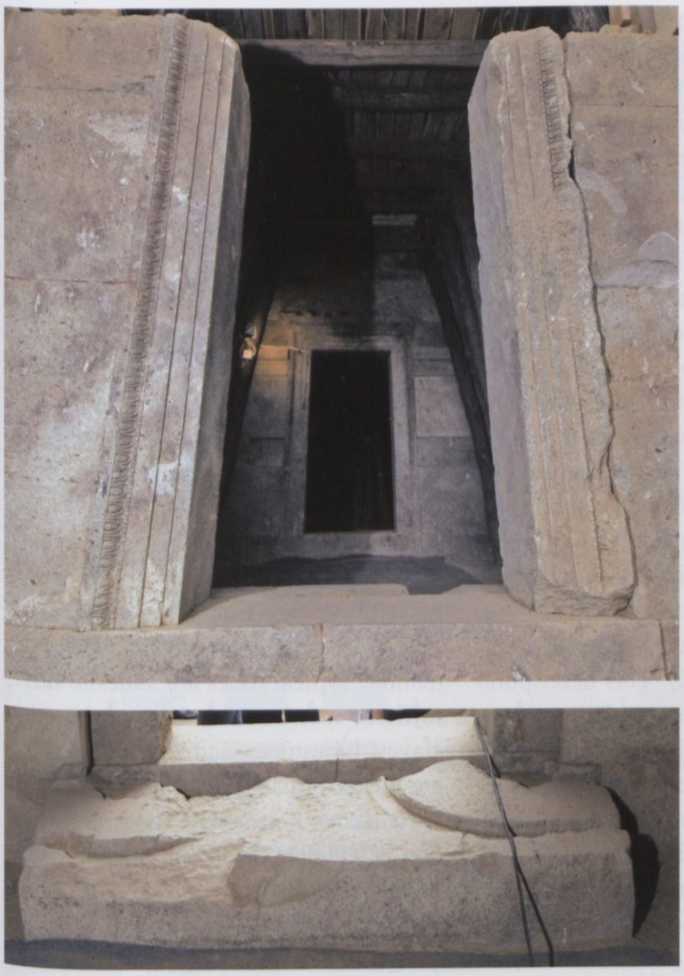

Fig. 58. Ionian doorframe leading to the antechamber in Chetinyova mogila (top) and detail of the lead chiseled for opening the stone wings of the door (bottom) (photo: K. Dimitrov)

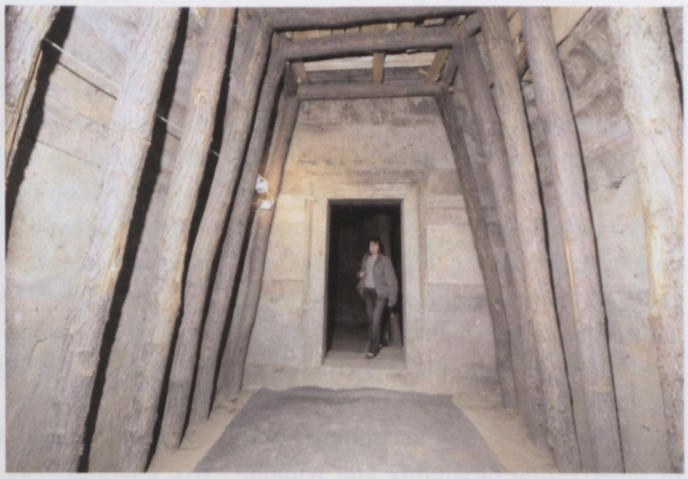

Fig. 59. The rectangular antechamber enforced by props (photo: K. Dimitrov)

Fig. 60. Upper beds of the stone door wing leading to the burial chamber (photo: K. Dimitrov)

classic archeological approaches are the slow and expensive ordinary excavation work that includes removal of the tomb mound, or motorized destruction of the tumulus and slow excavation only of the cultural layer.

A new approach is used to obtain access to the Chetinyova mogila tomb – mining technology. It is fast (excavation takes about 1 month), relatively cheaper than the classical methods and does not lead to the destruction of the tomb mound and this allows more attractive exhibition of the object in the future and guarantees security during discovery and preservation of the artifacts. The work plan of the support construction used in the antechamber and the burial chamber are shown in Fig. 62.

Fig. 61. Dorian entablature lying above Dorian semi-columns in the burial dome chamber of the Chetinyova mogila tomb (photo: K. Dimitrov)

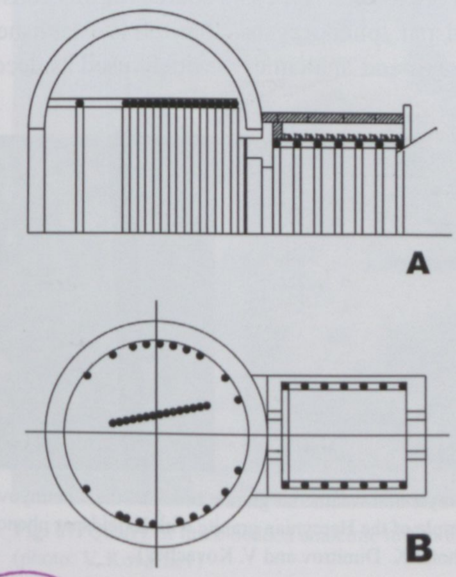

Fig. 62. Support construction scheme for the volume of the chambers in Chetinyova mogila, Starosel village showing the position of each support element used during the mining excavation (after Kovachev *et al.*, 2001)

A – profile;
B – plan view

After the excavation of the construction and the completion of the archeological investigation the dome shape will be cleared and prepared for the process of restoring the original shape of the dome and constructing support for the antechamber ceiling bearing beams (Atanasov, 2008; Fig. 63). These activities will lead to build again the dome and to remove the internal props without destroying the tomb mound. After this, the object is ready for exhibition at minimum investment cost, maximum interior preservation possibility and without any hazards to the environment.

Building materials

Fig. 63. Arc-shaped steel support of the dome shape over the burial chamber to allow for the restoration of the dome (photo: V. Kovachev)

The tomb in Chetinyova mogila to the north of Starosel village is an example of the stone construction progress. This building is spectacular in terms of both construction and architecture. The building consists of two rock types: granite with K-feldspar phenocrysts from the area of Hisarya and analcime-bearing medium- to fine-grained tuff quarried near Popintsi village (Fig. 53).

Both rock occurrences are also used by the modern construction industry, which corresponds to the heredity principle.

The reason for using two rock types is the difference of the purpose of the construction element, which they built up. The crepis (Fig. 56) is an external bearing and preserving element of the tumulus, thus it needs to be solid, resistant to weather influences and at the same time the material should bare certain decorative qualities. The walls of the dromos are relatively loaded from the sides, thus they also need to be made of solid rock, and thus again granite was used. It is coarse-grained leucocratic muscovite-biotite granite with K-feldspar phenocrysts (Fig. 64, left). This description fits the granites exposed in Hisarya area (Fig. 64, right).

The analyses of the soft building material used for the interior decoration shows that it is zeolitized fine-grained to ash-sized tuff. It is gray-green coloured, fine- to medium-grained, solid with no mesoscopic-scaled pores present. The rock appears spotted by small black grains that probably represent organic matter. Microscopically, analcime is identified as idiomorphic crystals or as micropores infill (Fig. 65).

The tuffs are relatively common rock type in Central Srednogorie, however such fresh, solid and non-fractured bodies are rarely exposed. Thus, finding the source for this construction material was hard. It is established that such rocks are widely used as decorative stones also in the contemporary buildings but the quarries are in Eastern Stara Planina Mountain (Aitos area). These localities are too far away from Starosel village. Based on the large amounts of the material found and the size of the blocks in Chetinyova mogila, it is concluded that it is least probable that these rocks came from those quarries. The investigation of the area around Starosel village shows that the corners and the eaves of the church in Smilets village (Fig. 66) are built using the same materials. This finding led to the conclusion that a more detailed field investigation should be applied to the area between the two villages.

The area is dominated by exposures of alternating Coniacian–Santonian, mostly volcanic rocks of Chelopech Formation. Typical rocks are andesite tuffs, tuffites interbedded by marlstones, clayey limestones and teffroids, which are unconformably overlain by rocks of the Mirkovo Formation. The first formation is widely exposed in Panagyurishte region reaching up to 600–700 m in width. The exposures of this formation closest to Starosel village are in the area to the west of Smilets village (Fig. 66).

The outcrop consists of andesite agglomerate tuffs, subordinate quantities of pyroxene-amphibole andesite and trachyandesite lavas and ash tuffs. The composition follows the normal to subalkaline series with potassium-sodium tendency. The lower quantity of ash tuffs in Chelopech Formation limits the possible quarry localities. The thick-bedded ash tuffs are present on the western bank of the valley of Luda Yana

Fig. 64. K-feldspar phenocryst in a weathered granite block of the Chetinyova mogila crepis (left) and weakly weathered rock sample of the Hercynian granite with K-feldspar phenocrysts in the quarry to the east of Hissarya (right) (photo: K. Dimitrov and V. Kovachev)

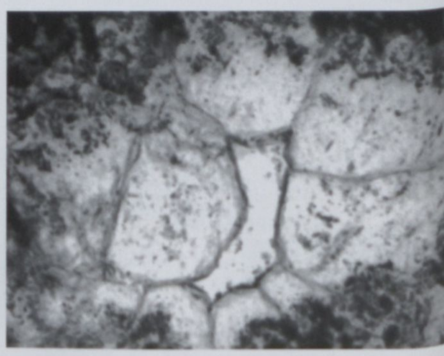

Fig. 65. Analcime crystallized in a micropore of a tuff that was used in the interior decoration of Chetinyova mogila (after Kovachev *et al.*, 2002)

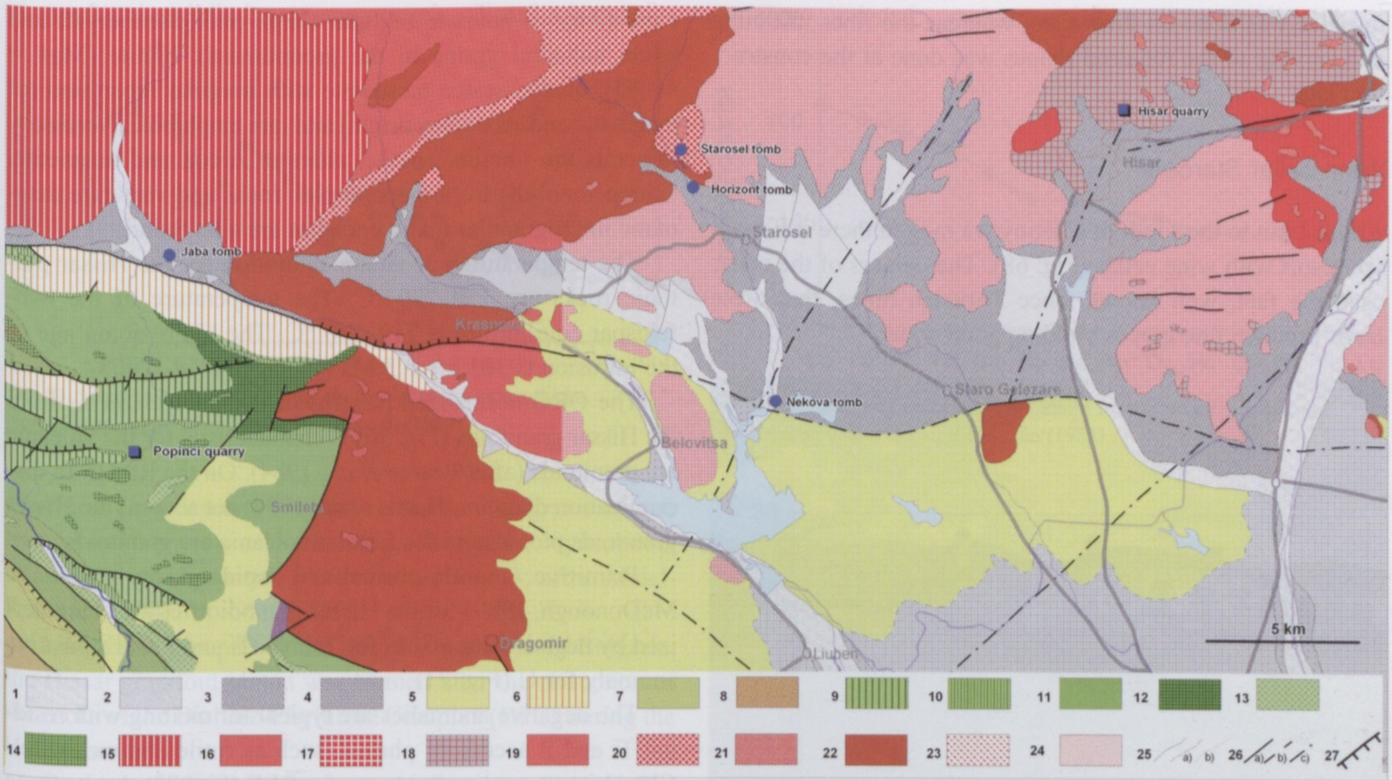

Fig. 66. Geological map of Starosel village area showing the location of quarries that sourced the building of Chetinyova mogila relative to the geology of the region (Geological Map of Bulgaria in scale 1:100,000)

Quaternary: 1 – Alluvial deposits – riverbed and flood plain (sands, pebble gravel); 2 – Proluvial deposits – drift fans (pebble gravel, sands); 3 – Proluvial-talus deposits (angular pieces, pebble gravel, sands); 4 – Alluvial-proluvial deposits (pebble gravel and sands); NEOGENE: 5 – Ahmatovo Formation (sands, gritstones, sandy siltstones); ***Paleogene***: 6 – Conglomerate formation (coarse to blocky unsorted polygenic conglomerates); ***Upper Cretaceous***: 7 – Porphyroid granodiorites – Elshitsa pluton; 8 – Gabbro and quartz diorites – Elshitsa pluton; 9 – Chugovitsa Formation (interbedding of marls, clayey limestones and calcareous sandstones); 10 – Mirkovo Formation (clayey limestones); 11 – Chelopech Formation (andesitic agglomerate tuffs and tuffites with interbeds of marls, argillites and clayey limestones); 12 – Tephroidal rocks, marls; 13 – Dacites and their tuffs; 14 – Andesites – sills and lava flows; ***Paleozoic***: South Bulgarian Granitoids – Third complex: 15 – Coarse-grained leucocratic two-mica granites (Strelcha pluton); Second complex: 16 – Porphyroid, biotite to two-mica granites (Koprivshtitsa pluton); 17 – Leucocratic coarse-grained, porphyroid biotite granites (Klissura pluton); First complex: 18 – Quartzdiorites, granodiorites, diorites, granites (Hisarya pluton); 19 – Porphyroid granites and granodiorites (Smilovene Pluton); 20 – Granodiorites – contaminated facies (Smilovene Pluton); 21 – Gabbrodiorites to peridotites (Smilovene Pluton); ***Precambrian***: Pre-Rhodopian Supergroup: 22 – Undivided Arda Group (migmatized banded and augen gneisses, inpersistent interbeds of amphibolites, gneisses and gneiss-schists); Hydrothermal metasomatites: 23 – Secondary quartzites; 24 – Propylitization; ***Boundaries***: 25 – Normal lithostratigraphic; of magmatic rocks; of Quaternary deposits: a) certain; b) uncertain, unconformable (transgressive); ***Faults***: 26 – Normal fault; fault of unknown character: a) certain; b) uncertain; c) buried; 27 – Reverse fault

River. These tuffs have the closest characteristic features to the ones of the rocks used for decorating the chambers of Chetinyova mogila. The exposures are turned into small contemporary quarries, however the negative forms in the riverbed attribute to the possibility that these areas were also the ancient quarries sourcing the tomb construction. The quarries excavate thick-bedded tuffs of pale green colour with low fracturing and with characteristic black inclusions (Fig. 67). The distance to Starosel village along a road of very small slope angles is less than 23 km (Fig. 53). The transportation distance also allows concluding that this area was a possible source of construction material for the decoration of the tomb chambers.

The construction of Chetinyova mogila tomb required perfect coordination for selecting and excavating the most efficient rock materials, their transportation and trimming as well as ensuring the availability of iron and lead for the chisel tools for working the blocks and for the clambs between these. Most probably the ruff working of the blocks excavated from the

Fig. 67. Quarry of thick-bedded analcime tuff in the area of Popintsi village (photo: V. Kovachev)

quarries was done on their sites, whereas the finer trimming and carving of the required shapes was done at the construction site.

Wine-cellar Starosel

About 1 km to the south of Chetinyova mogila there is a modern resort with wine cellar (Fig. 68). The owners of the cellar used the fact, well known since Thracian times, that these lands produce fine grapes yielding good wine.

Fig. 68. Wine-cellar and resort near Starosel village (photo: V. Kovachev)

The resort architecture resembles the typical XIX[th] century Bulgarian style still standing out with its own uniqueness. The resort includes production halls, hotel, restaurant, conference hall, sport area with pool and spa centre (www.Starosel.com). Under the ground level of the resort a bigger copy of Chetinyova mogila chambers is build, which is used as wine degustation halls and a scene for presenting close to authentic ritual dances of the Dionysus cult, the god of wine and ecstasy.

2.8. Field stop 8. Hissar granitic quarry

(V. Kovachev, R. Nedialkov)

The quarry (Fig. 69), supposed to have supplied the granite blocks for the construction of the crepide and the dromos at Chetinyova mogila, is located in the southern periphery of Hissar pluton, immediately to the east of the town of Hissar. The pluton is one of the numerous Hercynian granitoids in Bulgaria. The plutons Strelcha, Smilovene, Koprivshtitsa, Matenitsa and Klisoura (Fig. 66) between the town of Strelcha and Starosel village belong to the same group. However, they do not possess the decorative qualities of the porphyritic granodiorite from Hissar pluton. The porphyritic granodiorites are peripheral facial varieties of the mainly equigranular rock of the pluton.

The Hissar pluton is calc-alkaline and mainly metaluminous, with differentiation trend from diorites to granites. The prevailing rock variety is biotite granodiorite. The main rock-forming minerals of the different plutonic rocks are: plagioclase (An_{6-37}), potassic feldspar (large pink phenocrysts and white anhedral grains in the groundmass), biotite (Mg# = 40–53), quartz, scarce muscovite with irregular repartition (of magmatic and secondary origin) and rare amphibole. Accessory minerals are titanite, apatite, allanite, zircon and magnetite. Scarce xenoliths from metamorphic rocks and very rare magmatic microgranular mafic enclaves are also found.

The temperatures of zircon saturation for the Hissar plutonic rocks are 750–770 °C. The temperature of the two-feldspar equilibrium is 719–730 °C. The U-Pb zircon age of the intrusion is 303.5 ± 3.3 Ma (Carrigan *et al.*, 2005).

The ORG-normalized patterns of the trace elements from the Hissar granitoids (Fig. 70) is characteristic for the volcanic arc granitoids (after Pearce *et al.*, 1984). On the Rb-Hf-Ta discrimination diagram (Harris *et al.*, 1986; not shown) the Hissar granitoids plot also in the field of volcanic arc granitoids.

Primitive mantle-normalized spidergrams (Sun & McDonough, 1989) for the Hissar granodiorites are characterized by negative anomalies for Ta, Nb, Ti and P and a positive anomaly for U (Fig. 71).

The negative anomalies are typical for melting with residual Ti and P accessory phases (such as rutile and monazite). Chondrite-normalized patterns for REE (Fig. 72) demonstrate enrichment of LREE (La/Lu = 19) and presence of a slight negative Eu anomaly (Eu/Eu* = 0.72).

Fig. 69. The quarry for granodiorite with K-feldspar phenocrysts east of the town of Hissar (photo: V. Kovachev)

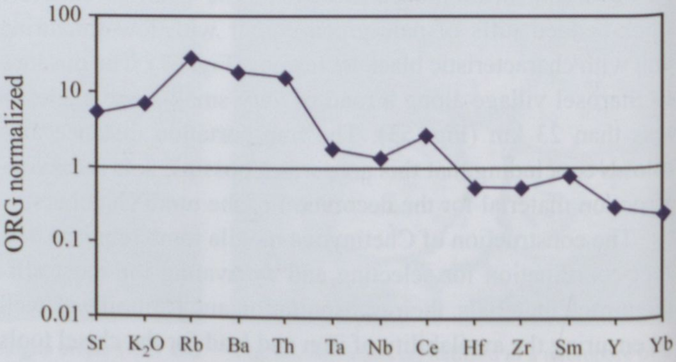

Fig. 70. Chondrite-normalized spidergram for the Hissar granodiorite. Normalizing values after Pearce *et al.* (1984)

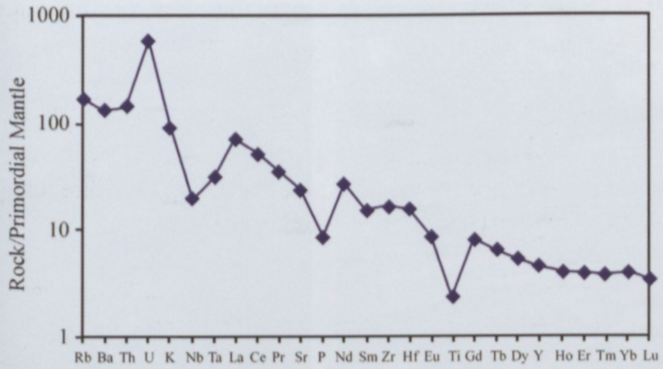

Fig. 71. Mantle-normalized spidergram for the Hissar granodiorite. Normalizing values after Sun & McDonough (1989)

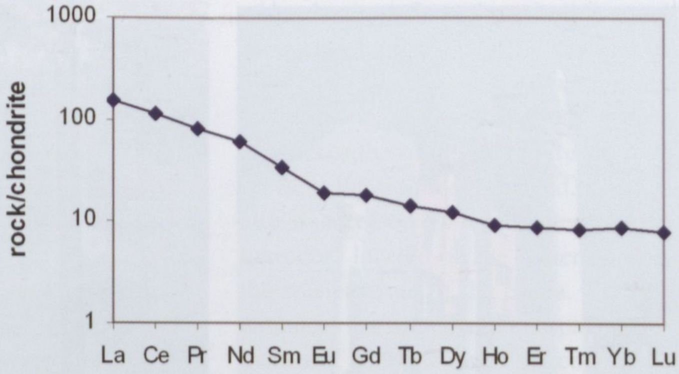

Fig. 72. Chondrite-normalized REE pattern for the Hissar granodiorite. Normalizing values are after Boynton (1983)

Chemical composition of biotite shows that the granitoids are transitional between calc-alkaline (volcanic arc, synsubductional) and peraluminous (collisional) (Fig. 73; after Abdel-Rahman, 1994).

Like the bigger part of the Hercynian plutons in Bulgaria, the Hissar granitoid pluton was formed after the obduction of the rocks of the Diabase-Phyllitoid Complex (DPC) during the Hercynian collision.

On this basis the pluton is assumed to be post-collisional. The plate tectonic model of Stampfli & Borel (2002) demonstrates that fragments of Gondwana collided with Laurussia 340 Ma ago (approximately 35–40 Ma before the formation of the pluton).

Based on all available mineralogical and geological data, the Hissar pluton can be assigned to the mixed granitoids (hybrid between acid and basic sources) – calc-alkaline granitoids (CAGS – after Patiño Douce, 1999) or K-rich calc-alkaline granitoids (KCG – after Barbarin, 1999). From a general point of view, they could be determined as post-collisional, but synsubductional element could not be excluded.

The Hissar granite at present is widely used in building industry (Fig. 53). The jointing is in three mutually perpendicular directions, which facilitate the production of blocks (ashlars) with dimensions up to 1 m. This can explain its application mainly in masonry.

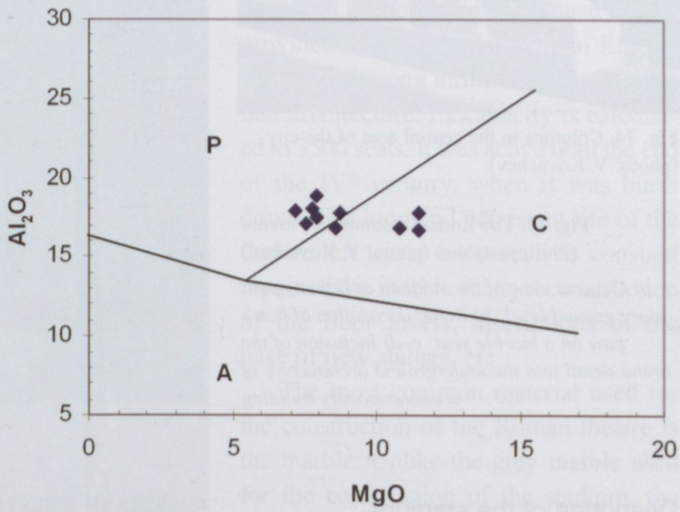

Fig. 73. Discrimination diagram based on the composition of biotites (after Abdel-Rahman, 1994). P – peraluminous granites; C – calc-alkaline granites; A – alkaline granites

2.9. Field stop 9. The ancient town of Philippoupolis

(Veselin Kovachev & Daniela Stoyanova)

The town of Plovdiv is the ancestor of the town Philippoupolis that was founded in pre-Roman times. Today this is the second largest town in Bulgaria and is located 110 km to the east of the capital Sofia. It expands over seven Upper Cretaceous syenite rock hills called Dzhendem tepe, Bunardzhik, Sahat tepe, Nebet tepe, Dzhambaz tepe, Taksim tepe and Markovo tepe. The latter hill was destroyed in the early XX^{th} century due to syenite production for pavement purposes. The old part of the city is located around the three hills – Nebet tepe, Dzhambaz tepe and Taksim tepe that the locals call "Three hills". Brief description of the town history is available at http://en.wikipedia.org/wiki/Plovdiv. The ruins of this great city before Roman times include mostly monumental fortresses located on Nebet tepe and Dzhambaz tepe hills. The Roman Age ruins, however, are even more impressive (Kesyakova, 1999). The focused attention of the archeologists in the last years resulted in the discovery of more and more relics of the history of the town. New data became available for the existence of a fortress system, for the orthogonal street network oriented in the four directions of the world; and for the characteristics of the public and civil buildings.

One of the most important areas of the city that rules its fate and controls its whole architectural plan is the Agora – the central place of the town (Fig. 74). The agora was first built in the I^{st} century BC and during the following centuries it was reconstructed and modified several times. The remains of two public buildings are the most remarkable. One of them is the stadium located to the north of the agora and the other one is the amphitheatre.

Fig. 74. Columns in the central area of the city (photo: V. Kovachev)

Fig. 75. The Roman stadium in Plovdiv (Philippoupolis) (photo: V. Kovachev)

a) General view of the stadium at Dzhumayata place ground level; b) Relief decoration of lion's paw on a marble seat; c–d) Inclusion of the arena detail into the underground architecture of a contemporary building

Desription of the stadium

The seat rows of the ancient Roman stadium are placed in amphitheatre order on the sides of two opposite hills – Sahat tepe to the west and the Three hills to the east. These rows mark one of the stadium ends and in its other end masoned pylons with pilasters are excavated and decorated by the face of Hermes and the attributes of Heracles. Today the place Dzhumayata features modern architecture and infrastructure in harmony with parts of the northern sphendone (semicircular end of the stadium) with an underground corridor and a sector of the arena.

Only 13 marble seat rows are preserved (Fig. 75a). The lowest row is separated from the arena by a podium of about 1.80 m height. The seat rows are cut by steep staircases. Some of the seats are decorated by lion's paw reliefs (Fig. 75b). The seat rows are also cut by a roofed entrance leading to an underground passage (Fig. 75c). Its ground consists of large rock plates cut by a channel. The arena architecture is of particular interest. The floor of the arena has three layers and a roughcast finish. The arena ruins are included in the construction of the underground floors of buildings that were built in the beginning of the XXI[th] century (Fig. 75c–d). The material used for the construction of the Roman stadium is grey marble with rare red-brown fractures filled by iron hydroxides.

Rarely, wider areas of the marble are coloured in red. This description matches the marbles excavated on the northern slopes of Rhodope Mountains located to the southwest of the town of Asenovgrad at a distance of about 22 km from the centre of the Roman city (Fig. 76).

Description of the theatre

The theatre is a dominating building in the city centre of any Roman town. Its location in Philippoupolis is the result of optimum combination of the possibilities offered by the ground relief and the city architecture. The natural funnel shape of the area between Taksim tepe and Dzhambaz tepe is used. The theatre faces the valley to the south. According to the inscription on the frieze of the southern proskenion, the building of the theatre began under the reign of Emperor Trajan between 108 and 114. Future additions to this construction were made during the Antoninian period – the reign of Emperor Hadrian and next during the Severan dynasty. The theatre consists of 28 amphitheatre seat rows divided by one step (diazoma) into two rangs (floors), each of 14 rows. The seat rows of the cavea are placed directly on the ground. The major parts of the theatre – the cavea, the underground passage under the skene reaching the middle of the orchestra, the open parodos (side entrances) belong to the original first construction of the theatre. In vertical direction the cavea is divided into radial sectors via steep stair-

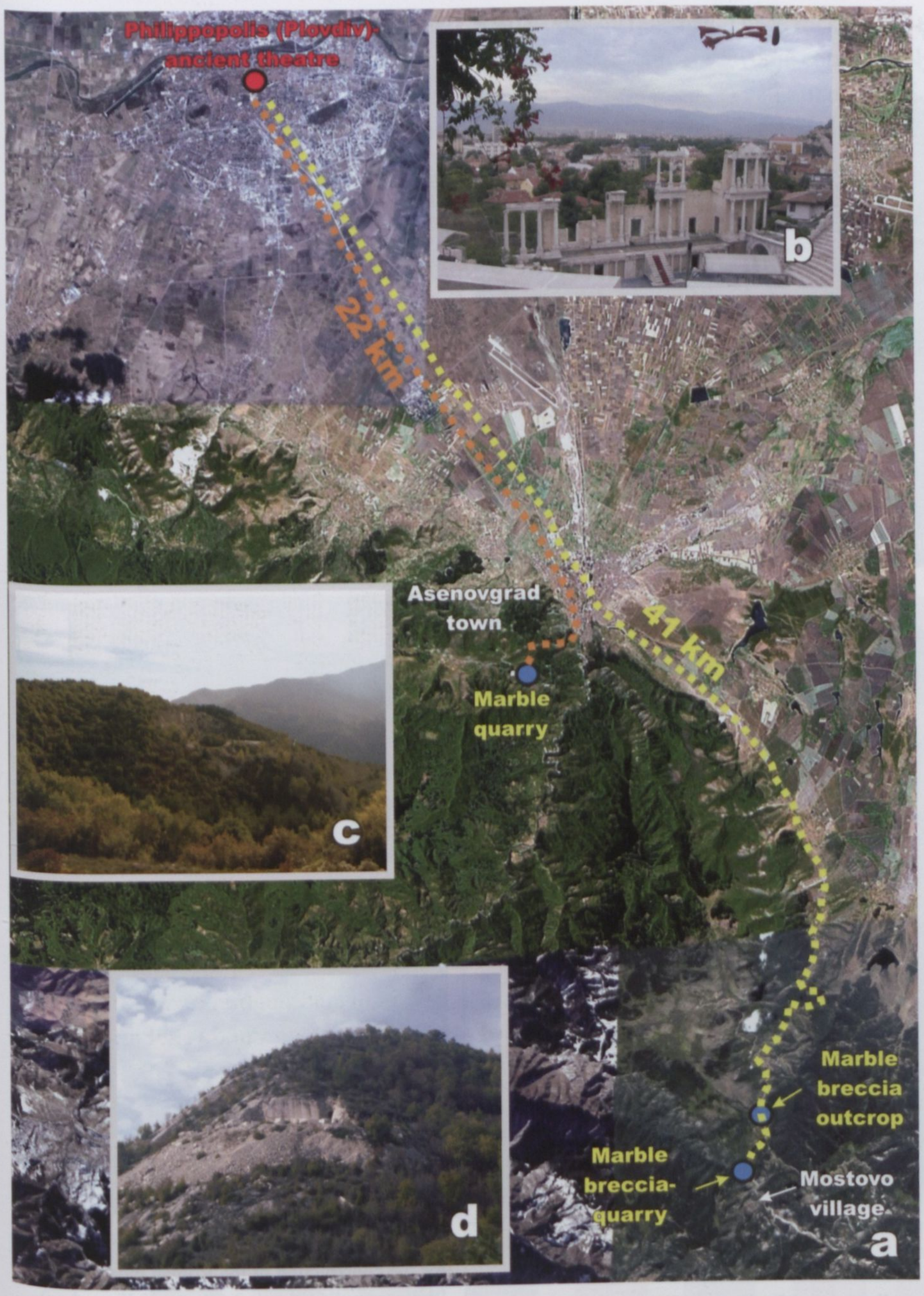

Fig. 76. Location and general view of contemporary quarries for marble and carbonate breccia production that were probably used for the construction of the Roman stadium and theatre in the city of Philippoupolis (Plovdiv) (photos and collage: V. Kovachev)

a – Satellite image of the area around the town of Plovdiv showing the location of the Roman theatre, the marble and carbonate breccia quarries possibly used during its construction and the road distances to the theatre; b – General view of the theatre; c – Contemporary quarry to the south of the town of Asenovgrad; d – Contemporary quarry near Mostovo village

cases that cut the seat rows (Fig. 77). The lower rang is divided into 6 sectors via seven staircases, where the two end staircases and the middle one cut the podium reaching to the orchestra. The other four staircases reach only the podium (Fig. 77). The uppermost seat row of the first rang has backrests. The radial construction of the upper rang (suma cavea) includes the northern entrance located at the base of the cavea axis reaching the diazome. In the summa cavea area this entrance is roofed.

The cavea looks at a semi-circle orchestra (play scene) of 26.64-m diameter (Fig. 78). Its southern side is limited by the three-flour skene building decorated according to the Ionic order. In both ends, the eastern and the western, there are premises (proskenion) that connect to the cavea and where the staircases to the floors are located. The theatre is accessed via two side entrances (parodos) located on the eastern and on the western side of the cavea. The side entrances are roofed and the space above their roof construction is not covered by seat rows (Fig. 78). The seats have inscriptions of the 10 phylas.

The architectural plan of the Roman theatre in Philippoupolis is typical for the province theatres in the Roman Empire and for the strong influence of the Anatolian architecture. Its capacity is calculated to 3500 seats. It was active until the end of the IVth century, when it was burnt down. The long and persistent life of the theatre left traces on it such as constant repair of the marble seats, reconstruction of the floor levels, inscriptions of the base of new statues, etc.

The most common material used for the construction of the Roman theatre is the marble. Unlike the grey marble used for the construction of the stadium, the Roman theatre is built of marble with various colouring (Fig. 79a). The marble is fine- to medium-grained with numerous small red coloured fractures (Fig. 79b). In some places it becomes gray (Fig. 79a) or appears as marble breccia (Fig. 79c). The architectural view of the orchestra is created by the combination of massive marble and marble breccia (Fig. 79d).

The general intention of the constructions of the Roman stadium and the theatre in Philippoupolis appears to be to emphasize on the impressiveness and on the decoration richness. Thus, better decorative quality marbles are used at the expense of those more resistant to weathering processes. Such types of marbles are exposed in the areas of Mostovo village (Fig. 76) at much larger distance (41 km) and the transportation must have been a complex process. The red coloured breccias are a common building stone in contemporary buildings as well as in ancient ones (Fig. 80).

Fig. 77. Cavea construction of the Roman theatre in Philippoupolis (Plovdiv) (photo: V. Kovachev)

Fig. 78. General view of the orchestra and the western side entrance of the Roman theatre in Philippoupolis (Plovdiv) (photo: V. Kovachev)

Fig. 79. The marble rocks used for the construction of the Roman theatre in Philippoupolis (Plovdiv) (photo: V. Kovachev)

a) Various colouring and structure of the marble used for the construction of the cavea staircases; b) Red-brown coloured fractures in the marble that builds the seats; c) Brecciated zones in the marble used for the construction of the cavea staircases; d) Restored (white areas) column of the orchestra built by marble breccia with red matrix

Fig. 80. Facings built of marble breccias with red-brown matrix of Hagia Sophia church in Istanbul (left) and in the facade of a contemporary building in the town of Stara Zagora (right) (photo: V. Kovachev)

2.10. Field stop 10. Asenovgrad marble quarries

(V. Kovachev)

The northern slopes of the Rhodope Mountains consist of the rocks of Sitovo Group and Dobrostan Marble Formation (Fig. 81). The outcrops closest to Philippoupolis (Plovdiv) are located near the town of Asenovgrad at about 20 km away from the Roman city. The outcrop consists of Sitovo Group rocks.

Sitovo Group contains mostly gneisses and comprises the following lithostratigraphic units:

- Boikovo Gneiss Formation;
- Bachkovo Leptinite Formation;
- Lukovitsa Gneiss-schist-Schist Formation.

These rocks build the core of the North Rhodope anticline. They overlie conformably the rocks of Rupchos Group and are covered by the marbles of Dobrostan Marble Formation of Asenovgrad Group. The marbles are characteristic for the upper levels of the group – the Lukovitsa Gneissschist-schist Formation.

Lukovitsa Gneiss-schist-Schist Formation consists of: the Mandra Member – muscovite gneiss, gneiss-schists and schists; the Ruen Member – amphibole-biotite gneiss-schists, schists, massive orthoamphibolites and metamorphosed basic volcanic rocks that overlie and are covered by two marble layers; the Bela Cherkva Member – kyanite-staurolite gneiss-schists with garnet and red biotite that are overlain by layers rich in graphitized organic matter; the Lyaskovo Member – two-mica and biotite gneiss-schists and schists; and the Yavrovo Member – calc-schists interbedded by marbles, mica schists and amphibolites. The characteristic feature of Lukovitsa Formation is that in its

Fig. 81. Schematic geological map of the region between the town of Asenovgrad and Mostovo village showing the possible source localities for production of marbles and marble breccia (Geological Map of Bulgaria in scale 1: 100,000 with corrections by the authors)

Quaternary: 1 – Proluvial deposits – drift fans (slightly reworked sands, pebble gravel, boulders); 2 – Talus deposits (pebble gravel, sands); 3 – Talus-proluvial deposits (boulders, pebble gravel, sands); 4 – Alluvial-proluvial deposits (boulders, pebble gravel, sands, clays); ***Neogene***: 5 – Ahmatovo Formation (pebble gravel, sandstones, clays, siltstones); ***Paleogene – Neogene***: 6 – Conglomerate-sandstone formation (sandstones, conglomerates, breccia-conglomerates); ***Paleogene***: 7 – Sandstone-clay-marl formation (clayey marls, siltstones, sandstones); 8 – Breccia-conglomerate-sandstone (olistostrome) formation (breccia-conglomerates, sandstones, marls, coal, bitumen); Dyke tensional complex: 9 – Bodies and dykes of latites to quartz-trachytes; 10 – Bodies of rhyolites, trachyrhyolites to trachydacites; 11 – Coal-bearing-sandstone formation (conglomerates, sandstones, clays, siltstones, limestones); 12 – Breccia-conglomerate formation (breccia-conglomerates, conglomerates); 13 – Continental terrigenous-limestone complex (breccia-conglomerates, siltstones, sandy and algal limestones); ***Upper Cretaceous*** ?: 14 – Fine-grained biotite granites; ***Precambrian***: Rhodopian Supergroup: 15 – Metaultrabasic rocks (metaserpentinites); Asenovgrad Group: 16 – Belashtitsa Carbonate-silicate Formation (carbonate schists, gneiss-schists, gneisses); 17 – Dobrostan Marble Formation (massive and layered marbles); Sitovo Group: 18 – Lukovitsa Gneissschist-schist Formation (biotite and two-mica gneisses, gneiss-schists and schists, marbles); 19 – Bachkovo Leptinite Formation (biotite and two-mica leptinites) and Boikovo Gneiss Formation (biotite and two-mica gneisses, amphibolites); 20 – Rupchos Group: Undivided Rupchos Group (biotite and two-mica gneisses, gneiss-schists, schists, leptinites, etc –) and Vacha Variegated Formation (amphibole-biotite, biotite gneisses, gneiss-schists, leptinites, calciphyres); Lithological bodies in all formations: 21 – Marbles; 22 – Amphibolites; ***Superimposed processes***: 23 – Diaphthoresis; ***Boundaries***: 24 – Normal lithostratigraphic; of magmatic rocks; of Quaternary deposits; unconformable (transgressive); ***Faults***: 25 – Normal fault; fault of unknown character: a) certain; b) uncertain; 26 – Nappe

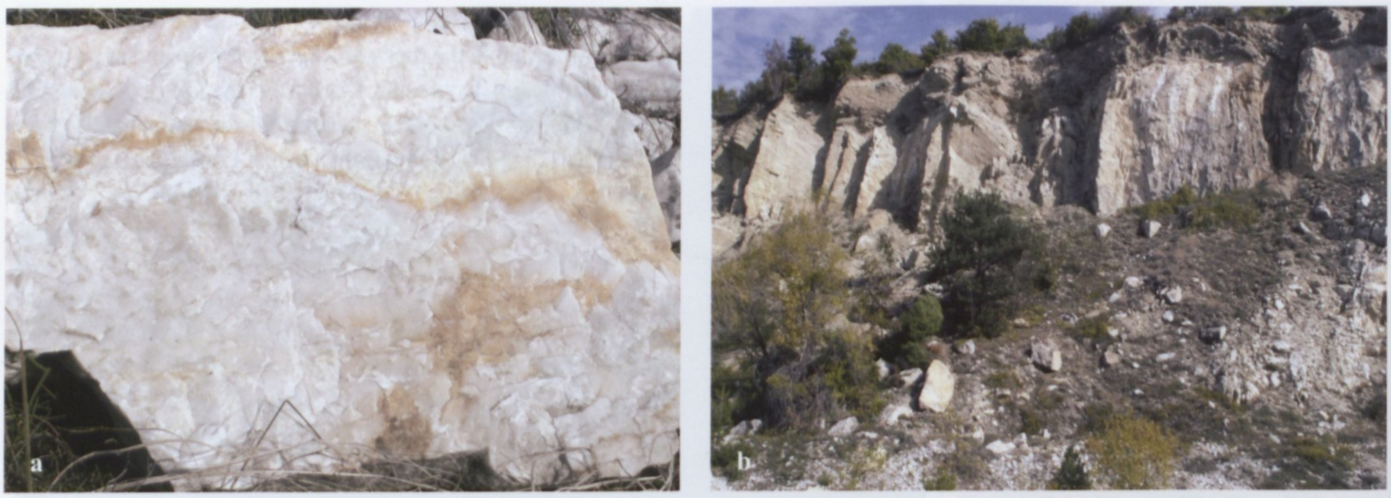

Fig. 82. Marbles from quarries in Asenovgrad area. Lukovitsa Formation of Sitovo Group
a) General appearance of the marbles; b) An area of thick-bedded and relatively less fractured marbles in the walls of the quarry

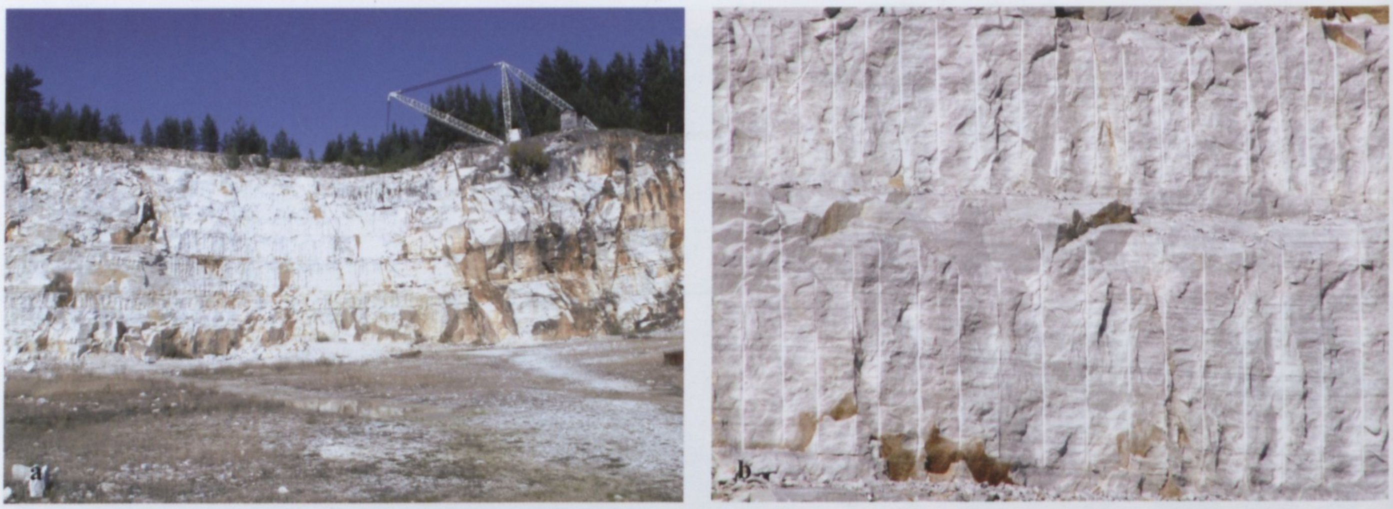

Fig. 83. White to grey marbles in Sitovo quarry of Lukovitsa Formation, Sitovo Group
a) General view of the quarry; b) Bedded grey to white coloured marble

upper levels the marbles become more abundant. The marbles in Ruen Member are laterally persistent and relatively thick (up to several tens of meters). They are easily traceable on the surface (Fig. 81) forming an anticline fold structure. These rocks are the possible source for the construction material used in the stadium at the ancient Philippoupolis. These rocks are excavated today in three quarries to produce marble (Fig. 76c) visible on satellite images (Google Earth, N41.98949 E24.84909).

The marbles are grey, medium- to coarse-grained, coloured in yellow or red-brown (Fig. 82a). The chemical analysis performed (Borisova & Borisov, 1961) shows that the rock contains variable amounts of $MgCO_3$ (0–3.70%) the low (up to 0.63%) $Fe_2O_3 + Al_2O_3$ content is related to the pale colouring of the marbles. The rock mass is fractured, thus today the excavation produces only crushed stone fractions. The density and the orientation of the fractures, however, allow the production of small blocks with the same size used for the stadium construction (Fig. 82b).

White to grey coloured marble with large calcite crystals and layered structure is present in Sitovo village area (Fig. 83). They belong to Lyaskovo Member of Lukovitsa Formation and expose the southwestern parts of the marble layer (Fig. 81). The characteristic features described here match the ones of the material used at the stadium. However, the transportation distance is relatively longer and the road slopes are less favourable for such intention. It is concluded that this quarry is less probable to be the source of building rocks.

2.11. Field stop 11. Mostovo marble breccias

(V. Kovachev)

Marble breccias with transition to massive marbles were used for the construction of the stage elements at the Roman theatre in Philippoupolis. The most important feature of this material is its decorative quality and its relatively good resistance to weathering especialy in their blocks with areas of more abundant matrix (Fig. 79).

This material type is widely exposed in the areas surrounding Mostovo village, which is too far (40 km) away from the Roman theatre (Fig. 76). The rocks exposed belong to Dobrostan

Marble Formation of Asenovgrad Group comprising mostly marbles (Fig. 81). The Asenovgrad Group builds up the northern periphery of the North Rhodope Anticline and represents the core of the North Rhodope Syncline. It consists of two formations: Dobrostan Marble Formation and Belashtitsa Carbonate-silicate Formation. The first formation contains most of the marbles present in the group and will be described here briefly.

The Dobrostan Formation lies with partial concordance over the rocks of Lukovitsa Formation and is concordantly covered by the rocks of Belashtitsa Carbonate-silicate Formation with rapid lithological transition. The formation contains three distinctive layers. The lower one contains grey, grey-white and banded medium-grained thick-bedded marbles. Rare interbeds of gneisses and schists are also present. This level is characteristic for the eastern and southern periphery of the syncline structure. The middle levels consist of white, grey-white and grey coloured fine- to medium-grained marble of mostly massive structure. The inclusions contained are of graphite, mica and quartz. The dolomitic component in the rocks increases towards the upper parts of the level. The medium level of the formation is common in the central parts of the North Rhodope Syncline. The upper levels are less abundant and are most common in the eastern pericline of the North Rhodope Anticlyne. These contain fine-grained, mostly grey-white to grey and white coloured dolomitic marbles with massive structure. In the upper parts of the level these rocks turn to pure calcite marbles. The thickness of Dobrostan Marble Formation reaches up to 1600 m.

The characteristic red matrix marble breccia used for the construction of the orchestra in the Roman theatre of Philippoupolis is exposed in several outcrops along the road between Oreshets and Mostovo villages. Here grey coloured, bedded marbles host pockets of brecciated carbonate material in a red-brown matrix (Fig. 84b). The transition between the massive rock and the brecciated zones is gradual (Fig. 84, a). There is no spatial relationship between the development of the marble breccia and the presence of tectonic structures. This implies that the most probable origin of the breccia is via karst processes. Besides the road outcrops, these rocks are exposed in a contemporary quarry, where the relationships between the massive marbles and the marble breccias are even more clearly observed. The comparison between the marble breccias near Mostovo village and the material of the decoration elements in the orchestra construction shows complete resemblance (Fig. 84). The lithostratigraphic position of the rocks near Mostovo village is at the lower levels of Dobrostan Marble Formation.

The source of marble and marble breccias used for the construction of the monumental buildings in the Roman city of Plovdiv is related to Lukovitsa Formation and Dobrostan Marble Formation exposed in the northern slopes of Central Rhodope Mountains (Fig. 76). Evidences of ancient quarries are not found in the area. Based on the road distance measured, most of the grey and the grey-red coloured marbles were produced from outcrops of Lukovitsa Formation to the west of the town of Asenovgrad, where the special marble breccias were transported from longer distances from quarries near Mostovo village (Fig. 76).

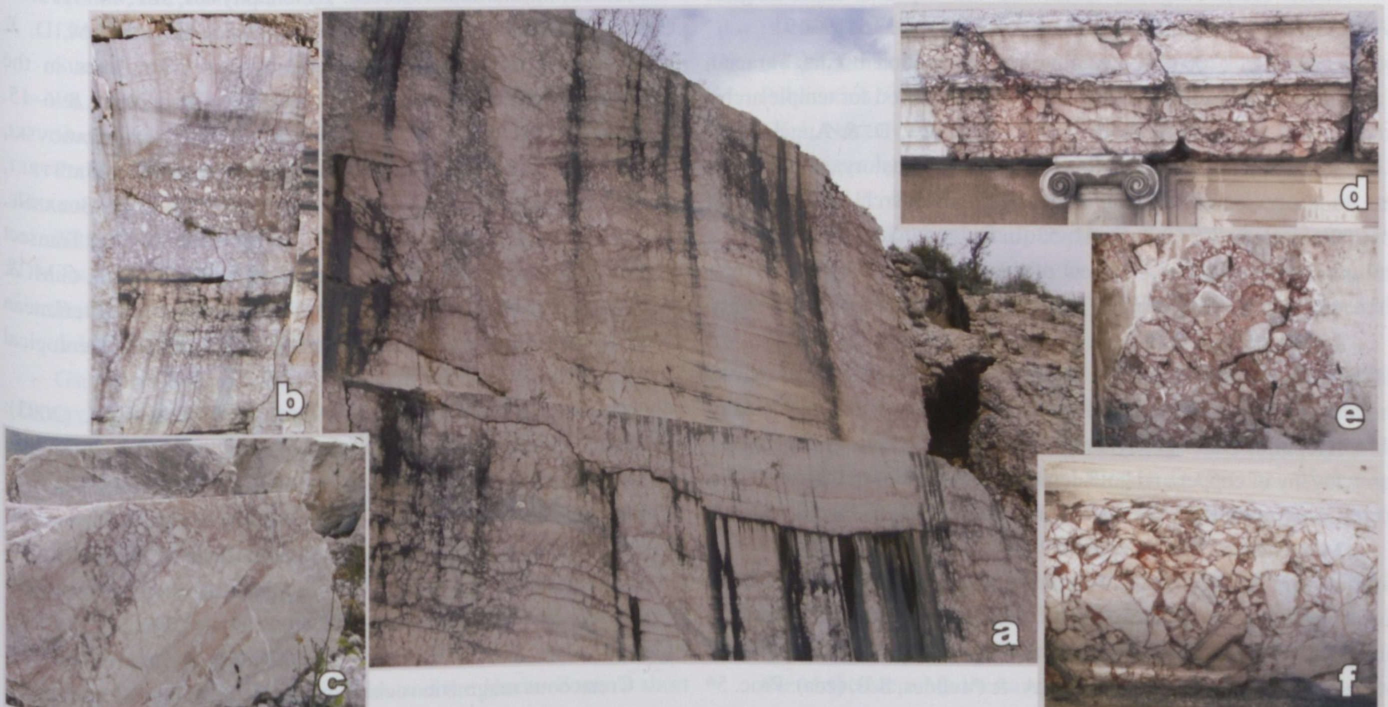

Fig. 84. Transitions between massive marble with local red colouring and the marble breccias with red coloured clayey matrix in the walls of the quarry near Mostovo village and examples of similar material in elements of the Roman theatre orchestra

a – General view of the quarry; b – Transition between massive marble and marble breccia; c – Surface of a block cut at the quarry; d – Marble Ionic order at the theatre stage; ĺ and f – Distinctive weathering of the marble breccia matrix as seen in elements of the stage decoration at the Roman theatre (photos and collage V. Kovachev)

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Appendix – Itinerary for IMA2010 BG1 Field trip

Friday, August 27, 2010 (Day 0): Travel to Sofia

Late in the night Arrival from Budapest to Sofia, accommodation

Saturday, August 28, 2010 (Day 1): Sofia and the National museum "Earth and Man"

10.00–15.00	Sightseeing in Sofia
15.00–17.00	Free time
17.00–19.00	Field stop 1: Visit to the National museum "Earth and Man"
19.00–	Welcome party in the National museum "Earth and Man"

Sunday, August 29, 2010 (Day 2): Field trip to Chelopech copper-gold mine and Koprivshtitsa town-museum (130 km)

07.00–08.30	Travel to Chelopech village
08.30–13.30	Field stop 2: Visit to Chelopech underground mine
13.30–14.30	Lunch
14.30–15.00	Field stop 3: Travel to the recreation complex of Chelopech mine
15.00–16.00	Presentation "Early copper and gold metallurgy"
16.00–16.40	Travel to Koprivshtitsa town
16.40–17.00	Accommodation
17.00–19.00	Field stop 4: Sightseeing in Koprivshtitsa
19.00–	Dinner and free time

Monday, August 30, 2010 (Day 3): Field trip to Asarel and Medet porphyry copper deposits, "Chetinyova mogila" Thracian tomb and Starosel vinery (100 km)

08.00–09.10	Travel to Asarel-Medet JSR
09.10–12.40	Field stop 5: Visit to Asarel open pit
12.40–13.40	Lunch
13.40–14.00	Field stop 6: Travel to Medet open pit
14.00–14.30	Observations on Medet open pit, ecological aspects
14.30–15.50	Travel to "Chetinyova mogila" Thracian tomb
15.50–16.50	Field stop 7: Visit to "Chetinyova mogila" Thracian tomb
16.50–17.00	Travel to Starosel wine cellar and hotel
17.00–18.30	Accommodation and free time
18.30–19.30	Wine tasting
19.30–	Dinner

Tuesday, August 31, 2010 (Day 4): Field trip to Hissar granitic quarry, the ancient town of Philippoupolis (Plovdiv), Asenovgrad marble and Mostovo marble breccia quarry, return to Sofia (340 km)

08.30–09.00	Travel to Hissar granitic quarry
09.00–09.30	Field trip 8: Hissar granitic quarry
09.30–10.20	Travel to Philippoupolis (Plovdiv)
10.20–12.00	Field trip 9: Visit to the ancient town Philippoupolis (main street, stadium and theatre)
12.00–12.35	Travel to the marble quarry at Asenovgrad
12.35–13.00	Field trip 10: Visit to the marble quarry at Asenovgrad
13.00–13.30	Asenova castle, lunch (sandwiches)
13.30–14.30	Travel to Mostovo village
14.30–15.30	Field trip 11: Marble breccia in surface outcrops and in quarry (at will)
15.30–15.50	Travel to resort village “Starite kashti”
15.50–16.30	Cofee break
16.30–18.30	Travel to Sofia
18.30–	Accomodation and free time

Wendesday, September 1, 2010 (Day 5): Tour in Sofia, free time and departure